

THE PAST AND THE FUTURE

BY

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Forecasts of spring water supply, which have for many years guided the operation of reservoirs, have been receiving renewed interest because of the increasing value of hydroelectric energy and the increasing concern over instream flow issues. In the Columbia River reservoir system, water supply forecasts become key operational factors as early in the year as January 1st, and may continue to form the basis for reservoir operation into the summer period. Based upon these forecasts electrical energy will be marketed (Gordon and Lamb, 1980), flood control space will be provided, and decisions on flow releases for irrigation and instream flow use will be made. With operating benefits in the Columbia River system being measured in terms of hundreds of millions of dollars annually, a very significant value can be placed on water supply forecasts and the need to reduce forecast error.

Long term water supply forecasts have traditionally employed multiple regression techniques to establish a relationship between spring runoff and variables such as snow water equivalent, precipitation, soil moisture and other measurable hydrometeorological factors. These techniques have been documented throughout the history of the Western Snow Conference. In more recent years conceptual hydrologic models have been employed for forecasting, although primarily on a short-term basis. The ability of conceptual models to simulate snow accumulation as well as melt was demonstrated by Rockwood and Anderson (1970), and others, and this suggested that simulation methods could be used for long term forecasts as well. The operational application of such techniques has been demonstrated by Pearson (1974); and Twedt, et al, (1977) demonstrated a method of statistically analyzing long term simulation results.

This paper discusses studies made that demonstrate the applicability of the SSARR (Streamflow Synthesis and Reservoir Regulation) model in making the long term forecasts of spring water supply in the Santiam River Basin for operation of Detroit Reservoir. It compares the results of simulation-produced volumetric forecasts with those derived by traditional multiple-regression techniques. Some advantages (and disadvantages) of model simulation as a means of producing water supply forecasts for reservoir operations are suggested.

STUDY BASIN

The comparison of runoff forecasting techniques was made on the North Santiam River at Detroit Dam, in Western Oregon (See Figure 1). This basin is typical of western Cascade catchments wherein winter precipitation is frequently accompanied by high freezing levels, resulting in copious rates of runoff, sometimes of flood-producing magnitude. Snow is also accumulated during the winter and is melted in the spring. The spring snowmelt runoff is relatively low in terms of total annual volume but is nonetheless important in the operation of Detroit reservoir. With a drainage area of 437 sq mi (1132 sq km) the basin has a annual runoff of 1,630,000 acre-feet (2.0×10^9 m³) or 70 inches (1778 mm). Normal annual precipitation in the basin is 85 inches (2157 mm). Approximately 35% of the annual runoff volume occurs in the March-through June period that has been selected for the forecast study.

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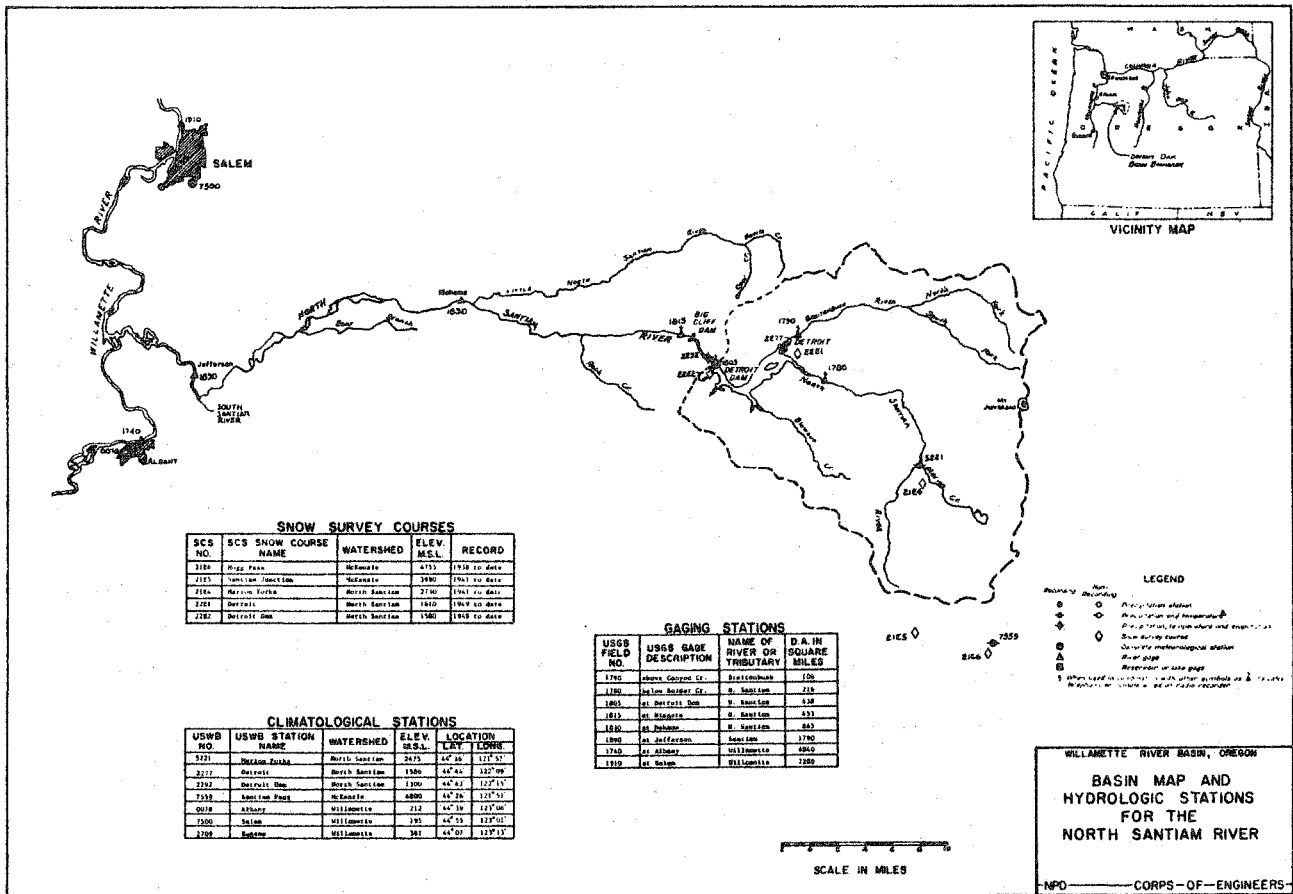


Figure 1 - Study Basin

The Detroit Project was constructed in 1952 by the U.S. Army Corps of Engineers as an element in the 11-dam flood control system for the Willamette River valley. This project also has a 100 mw powerhouse and is operated with concern for lake recreation and summertime low flow augmentation as well as flood control and power. The seasonal operating scheme dictates that the reservoir be at its lowest levels during the winter flood period so that storage space can be used to reduce downstream flooding. In February the reservoir is allowed to fill, and, if water supply is adequate, the lake will be at its normal full pool level by May. Late summer drawdown regains the winter flood control space and provides flow augmentation. It is in the spring filling of the reservoir that runoff forecasts are used to guide operations.

EXISTING SPRING RUNOFF FORECAST PROCEDURE

A multiple-regression forecast procedure (Corps of Engineers, 1968) has been utilized for forecasting spring runoff into Detroit reservoir. The procedure uses a basin average snow water equivalent and a spring precipitation index as the independent variables. The snow term is based upon measurements at four snow courses, while spring precipitation is determined from one gage with less weight assigned to precipitation occurring in later months. For purposes of this study the correlation was recalculated to reflect up-to-date data, but no attempt was made to change the procedure. Figure 2 shows the comparison between observed and forecast runoff, with all precipitation data known. The standard error of the correlation is 7% of the mean runoff. Since the spring precipitation component is relatively high in this basin, forecasts that must assume median precipitation have a considerably increased error. The 1 March forecast, for instance, has a standard error that is 17% of the mean.

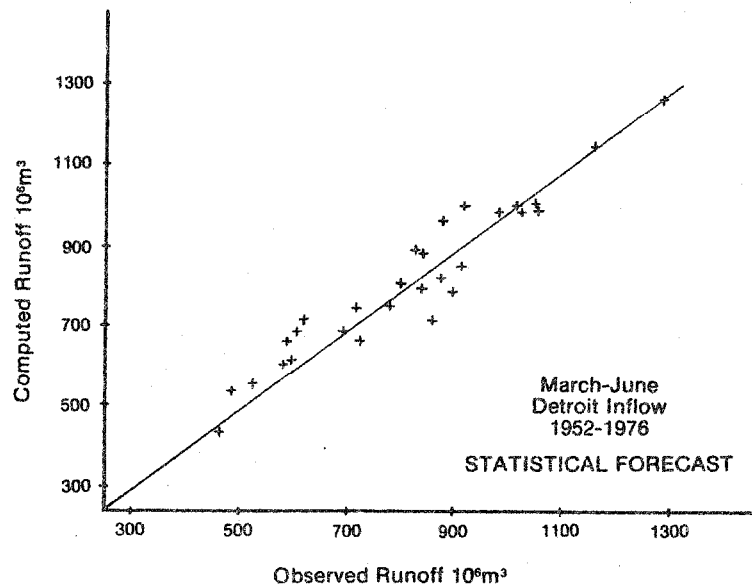


Figure 2 - Observed vs Computed Runoff, Statistical Forecast

NEW FORECAST MODEL

A continuous, conceptual hydrologic model, the SSARR (Streamflow Synthesis and Reservoir Regulation) program was employed to simulate the hydrologic regime of the Detroit basin. The SSARR model, described in numerous papers (Rockwood, 1968, Rockwood & Anderson, 1970) has been used for the past 25 years for short and medium-term forecasting of Columbia River streamflow and for simulation of system reservoir regulation for operations purposes. It is also used for winter flood forecasting in the Willamette River, and so SSARR short-term flood forecasts guide the flood control operations of Detroit and other Willamette flood control reservoirs. For this study the "snow-band" module of the program was used so that snow accumulation and runoff can be simulated in detail (Speers, et al 1978). In normal day-to-day forecasting, alternative routines have been used that require less data processing effort. The snow band routine treats precipitation, snow accumulation and ablation, soil moisture, evapotranspiration, and runoff independently on as many as 20 elevation zones. It is operated continuously throughout the water year and thus is capable of simulating both high and low flow periods.

For this study the Detroit watershed was subdivided into three subbasins, each divided into 10 elevation zones. Two precipitation gages and one temperature gage provided index to basin precipitation and temperature. The model distributes precipitation to each zone according to a fixed relationship. Zone temperatures were determined by using a fixed lapse rate, although the program has the capability of handling a variable lapse rate. The model was calibrated on a 11 year period of record, 1965-1975, using a calculation interval of 6 hours. Figure 3 shows the results of the calibration for two of the 11 years. The model "tuning" was done on a subjective basis with equal consideration given to winter and spring periods; i.e., no attempt was made to deliberately minimize spring volume errors in the calibration process. The reproduction of spring volumes is shown on Figure 4, along with the same years for the statistical procedure. A comparison of the plots indicates that forecast error for the SSARR model is approximately equal or slightly better than that achieved with the regression procedure.

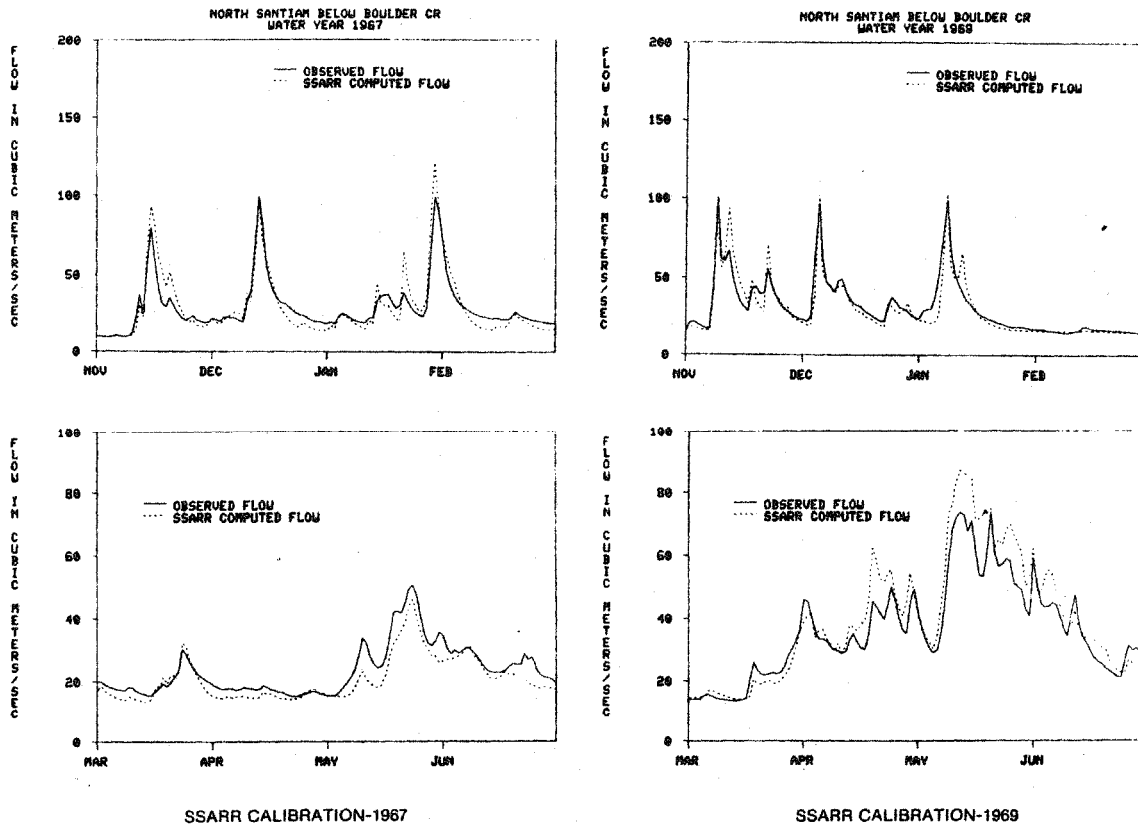


Figure 3 - SSARR Calibration, 1967 and 1969

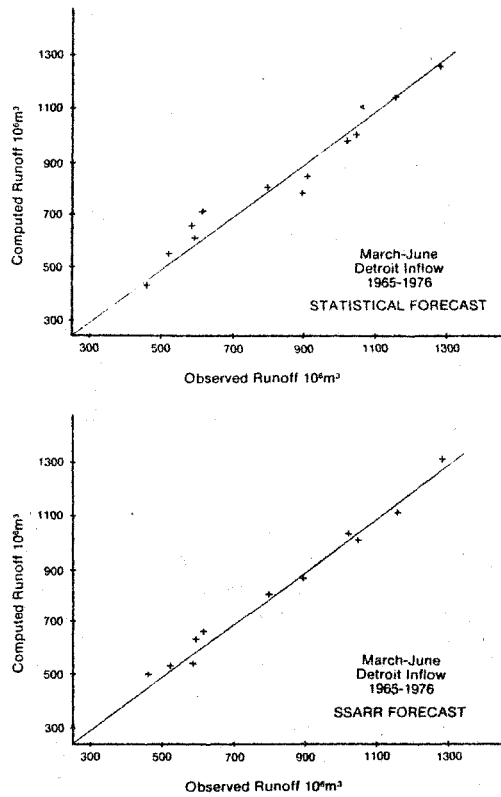


Figure 4 - Comparison of Statistical and SSARR Forecasts

COMPARISON OF FORECAST TECHNIQUES

Forecast Accuracy - As indicated above, comparable accuracy between the two approaches in water supply forecasting can be attained. However, it should be noted that the results shown for the hydrologic model represent a completely "raw" forecast; the model has been freely run to simulate several months of streamflow without correcting for obvious errors which result primarily from the inability of the temperature and precipitation stations to reflect basin-wide conditions at all times. In a "real-life" forecast situation the model simulation can be continuously checked against several recently observed parameters to correct current performance and, ultimately, improve water supply forecast accuracy. Although it has been shown (Tangborn, 1977) that statistical models can also be corrected by comparing forecast performance on a test sample, a simulation model is continuously computing several hydrometeorological factors on a realistic basis that can be compared with field measurements. This should provide a more reliable and consistent means of model adjustment.

One means of correcting the model is to compare computed snow accumulations with observed snow measurements. Kuehl (1979) showed that relationships between computed band snow water equivalent and field measurements could be derived from calibration simulations, and then applied to forecast runs to adjust the computed snow accumulation. He showed that overall forecast performance could be improved by this adjustment. Although no such adjustments were reflected in results shown in Figure 4, there is no doubt that snow observations will enhance forecast accuracy in the Santiam basin. Figure 5 is a plot of computed snow water equivalent versus snow course measurements, indicating that a definite relationship exists that could be employed to make model corrections. New SNOTEL stations will make the snow observations available on a real-time basis.

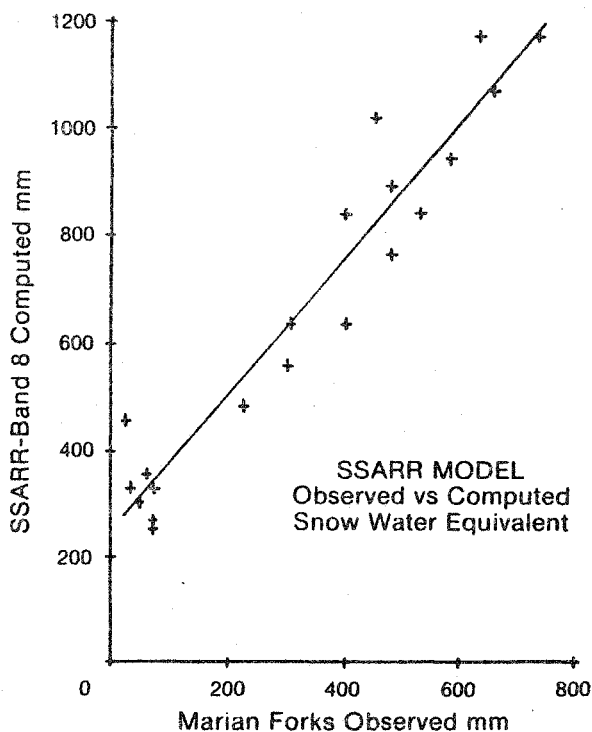


Figure 5 - Comparison of Observed and Computed Snow Water Equivalent

A second correction technique involves the continued adjustment of the model to past observed streamflow as the season progresses. This of course can be done with a statistical model as well, but with the conceptual model the adjustments can be made more frequently and should produce earlier and more refined corrections to the forecast. This is illustrated by the simulation of the 1977 runoff (Figure 6), an extremely dry year that was not reflected in the 11 year calibration period.

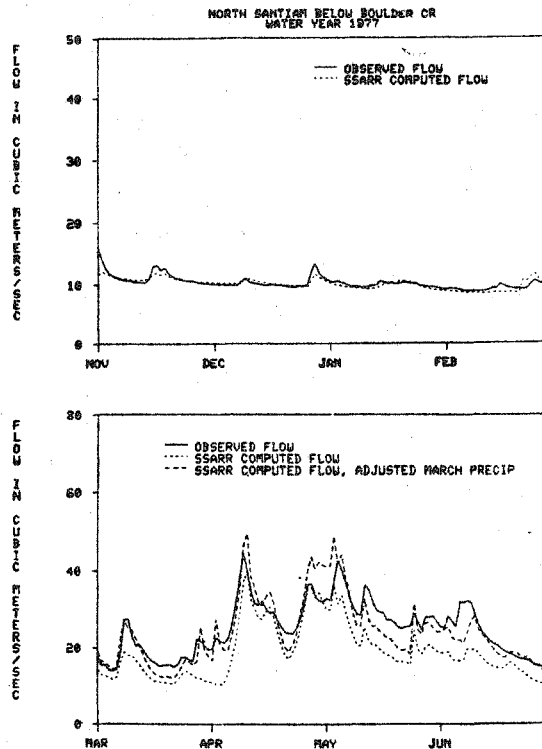


Figure 6 - 1977 SSARR Forecast

In this event the model's unadjusted reproduction of the spring volume had a relatively high error, although less than that of the statistical procedure. In Figure 6 an adjusted reproduction is shown, representing a "re-calibration" made on 1 April in which observed streamflow is attempted to be reproduced by, in this case, increasing precipitation over what was represented by the index gage readings. The result not only increases streamflow in March but raises high level snow accumulation that increases subsequent runoff volume and reduces forecast error. In a "real life" station such corrections, made at any desired interval throughout the year, would also involve checks against temperature and snow measurements to insure that a realistic change was being made. For the illustration shown, a comparison of Detroit inflow volume produced by the two procedures using observed subsequent precipitation and temperature data, are as follows:

	<u>March-June Runoff 10^6 m^3</u>	
	<u>Forecast Date</u>	
	<u>1 Mar</u>	<u>1 Apr</u>
Statistical Procedure	687	614 *
SSARR, unadjusted	526	555 *
SSARR, adjusted	-	594 *
Observed	600	

* Computed residual volume plus observed March volume.

The 1 Apr statistical forecast is based on a 1 Apr S.W.E. observation.

In the above illustration, the adjustment was made to the SSARR forecast after the first of March. This was necessary because virtually no precipitation occurred during the winter. In most years, earlier precipitation and runoff activity would permit an adjustment to the 1 March forecast.

Forecast Products - An advantage of the water supply forecasting with the SSARR model is that the forecasts can be expressed in a variety of ways to provide better products for reservoir managers. In this study the watershed output was tied directly with the Detroit reservoir model to provide calculations of reservoir filling throughout the spring period. An example of a refill forecast for 1977 is shown on Figure 7. Here a range of refill possibilities is shown, corresponding to different probabilities of the magnitude of spring precipitation under an assumed distribution pattern. In 1977 the snowpack on 1 March was so low that severe lack of refill was a definite possibility. Forecasts of this type were actually used to in 1977 guide decisions on special outflow rates that would enhance reservoir filling. As it turned out, relatively high precipitation occurred during the spring resulting in nearly complete refill, as shown.

Another application of the hydrologic model of course, is that it provides short term forecasts as well as water supply forecasts. Thus, one model can be used for a range of forecast applications, from short term winter flood control operations to long range drought assessments.

One forecast product not easily attainable with the hydrologic model is a uniform and simple calculation of forecast standard error that can be used in the determination of operating rule curves for reservoir operations. Such error estimates, defined by interagency operating agreements such as the Pacific Northwest Coordination Agreement, are readily available with a statistical procedure.

Ease in Development and Application - It is clear that the use of hydrologic models as a forecast tool presents a far greater degree of complexity to a user, as compared with a statistical procedure. Setting up and calibrating the hydrologic model is inherently a more subjective process, requiring experience and judgement. Once the model is calibrated and data processing procedures are established, however, production runs can be generated rather routinely.

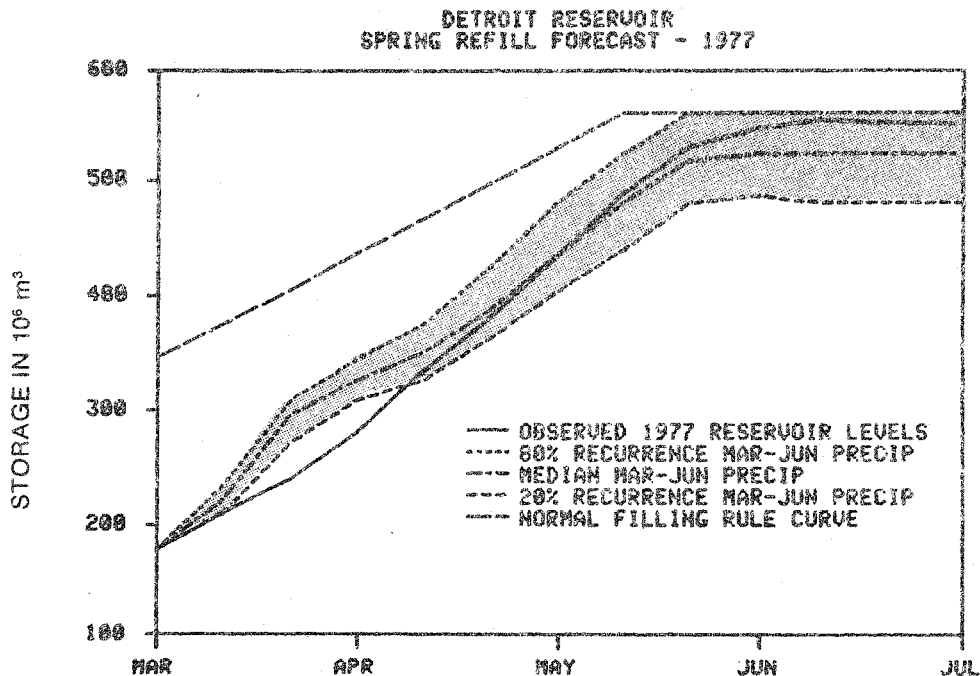


Figure 7 - SSARR Reservoir Refill Forecast

CONCLUSIONS

This study has demonstrated that continuous simulation with the SSARR model can produce long-term water supply forecasts in a typical "rain-on-snow" basin with accuracy comparable to a traditional multiple regression forecast. The simulation approach, however, offers, several advantages over a statistical forecast, in that accuracy can be improved by continually adjusting the model to match observed hydrometeorological conditions and that a greater variety of useful forecast products can be generated.

Despite the fact that water supply forecasting by hydrologic simulation is a much more complex approach than using statistical procedures, it is seen by the Corps of Engineers as worthy of continued development and application to guide reservoir operations. Although simulation will not likely replace statistical forecasts, at least in the near future, it will surely see increased application at key forecast points.

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