Adoption of
Hydrologic Design Criteria Recommendations
Lake Tahoe Basin, Nevada & California

SWQIC
Lake Tahoe Storm Water
Quality Improvement Committee

US Army Corps
of Engineers ®
Sacramento District

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LAKE TAHOE BASIN, NEVADA & CALIFORNIA

1.0 Introduction: A letter report dated December 2006 was provided to the Lake Tahoe Storm Water Quality Improvement Committee (SWQIC) for review. The purpose of the report was to summarize the products completed for the study to update hydrologic design criteria in the Lake Tahoe Basin for use by designers and local jurisdictions. The purpose of the study was to provide recommendations and tools for standardizing and improving hydrologic design methods within the Lake Tahoe basin. The products can be useful for traditional drainage design (e.g. storm drains) or for design of Best Management Practices (BMPs) such as detention basins for improving water quality. The recommendations are based on an analysis of current engineering practice in the basin, a review of recent scientific studies considered pertinent to Lake Tahoe, and detailed studies of the hydrologic characteristics for the study area.

Following review of the letter report, SWQIC requested that a more succinct report be produced for adoption by SWQIC and to highlight the primary recommendations for use in hydrologic design applications. In addition, the Hydrology and Hydraulics Subcommittee of SWQIC coordinated a workshop held on April 11, 2007 to summarize the final products produced and how they can be applied in the Basin. All final products are available at:

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In addition, the April 11 workshop was videotaped and is also available on the above ftp site link. Recent written comments from various agencies have written responses available on the above ftp site as well.

The following report sections present the background of work completed and recommendations should be considered for use in the hydrologic design of water quality improvement projects. Please keep in mind that local jurisdictions still need to consider the adoption of these design recommendations into their applicable land development codes or ordinances.

2.0 Methodology: The work was performed by employees of the U.S. Army Corps of Engineers (USACE). The recommendations focus on watershed modeling methods for estimating high frequency and risk based design flows (examples being the 2- and 100-year peak flows). Separate recommendations are made for watersheds located at elevations above and below 7,000 feet. This division is needed since long-term stream gage data is not available for small watersheds lying below 7,000 feet. Reviews of current local jurisdiction and professional practice (SPK, 2005b) and watershed calibration modeling studies (Cold Regions Research and Engineering Laboratory, 2005) provided the information needed to develop the recommendations for watershed areas lying below 7000 feet.

3.0 Products and Recommendations: A more detailed description of the Corps analysis and results is provided in the Corps Summary Report (SPK, 2007).

3.1 Hydrology Design Criteria Products

1. Report comparing National Weather Service (NWS) precipitation frequency study (NOAA Atlas 14, 2003) to Lake Tahoe region gaged precipitation data. The Corps concluded that NOAA 14 Atlas should be used for hydrologic design in the basin (see SPK, 2006).

   NOAA 14 Atlas precipitation depths can be accessed at the web link: < http://hdsc.nws.noaa.gov/hdsc/pfds/index.html >. The site provides point specific values for various frequency events and durations (5 minutes to 60-days). GIS based digital maps of the data can be downloaded for free.

2. Development of Regional Flow-Frequency Regression Equations for Lake Tahoe. The equations predict the following:

   a. Peak flow frequency curves
   b. 1, 3, 7, 10, 15, and 30-day annual maximum flow frequency curves
   c. 7-day annual *low flow* frequency curves (water quality applications, low-flow in summer can have highest concentration of some nutrients)
   d. Annual flow-duration curves (useful for ecosystem restoration or water quality analysis)

   Note: *The equations are limited to watersheds that have a significant contributing area above 7,000 feet and which have a drainage area of at least 0.5 square mile or larger.*

3. GIS Database: The Corps will provide three unique GIS maps, two of which are to be used as input parameters for the Regional Regression Equations. The Corps is working with TRPA to locate the data on the www.TIIMS.org website for use by designers.
   a. High Resolution Mean Annual Precipitation Map of Lake Tahoe derived using Oregon State University PRISM technology.
   b. High Resolution Mean Annual Snow for Lake Tahoe derived using Oregon State University PRISM technology.
   c. Antecedant Snow Water Equivalent (SWE): Shows the expected snowpack water content (inches) existing around Lake Tahoe when the one-day annual maximum discharge occurs. It is a synthetic snowpack derived for modeling hypothetical rain-on-snow events). The map is based on analysis of SWE data provided by the NRCS. A regression analysis was used to obtain an estimate of the SWE area variation.

      Note: *The Corps recent development of "effective soil loss rates" which incorporates snowpack effects has negated the need for this dataset. Nevertheless, it will be provided on TRPA's TIIMS.org website for use by interested scientists and others.*

3.2 Watershed Modeling Recommendations (detailed recommendations for engineers provided in SPK, 2007).

The recommendations propose that watershed modeling methods derived from calibration to gaged precipitation and runoff data are better than those based on an ungaged analysis (i.e., determined from the physical characteristics of the watershed). Consequently, the regional regression estimates should take precedent in all watershed areas where they can be applied. This is a key finding and recommendation of the Corps work and can be very useful in calibrating watershed models or to judge if watershed model predictions are reasonable (compare with regression model prediction confidence limits). The regression equations can be used to calibrate/validate watershed model predictions by any of the following: 1) adjusting model loss rates so that the model predicted frequency curves agree with the regression prediction within some reasonable tolerance; 2) adjust the model loss rates if necessary to ensure that model predictions lie within predicted regression confidence limits on frequency curves of interest; or 3) average model and regression predicted frequency curves. The method to use will depend on confidence placed in watershed model predictions.

The calibration studies (CRREL, 2005) determined that snow-affected runoff is critical to determining design runoff within the Lake Tahoe basin. Of concern is that most text estimates of runoff parameters (loss rates, runoff coefficients and routing parameters) have been developed for snow-free ground situations. Consequently, although smaller drainage areas lie outside the range of those used in the regression and calibration studies, the finding that snow-affected runoff is dominant within the basin needs to be considered, and until additional studies are performed, loss rates recommended in Table 1 should be applied in all undisturbed, open areas of the project watershed below 7,000 feet.

The Corps suggests using event-oriented models such as HEC-1 or HEC-HMS as opposed to more sophisticated continuous simulation or physically based models, given our knowledge of current practice. This is done with the caveat that the work being performed in support of the TMDL program (in conjunction with the Lahontan Regional Water Quality Control Board (Lahontan) and the Nevada Department of Environmental Protection (NDEP)) should also be considered. Local jurisdictions may wish to consider applications with new models being developed for this program depending on their success.

Specific watershed modeling recommendations are as follows:

1. Watersheds > 0.5 mi^2 and at or above 7,000 feet:

Peak flow and volume frequency can be estimated using the Regional Regression Equations. In the case where applicable streamgage data is available nearby, a frequency curve derived from the gage record might be more accurate, depending upon the quality and number of years of the data. Comparison of streamgage frequency curves and those derived from the regression equations is recommended. When hydrologic modeling is desired, watershed modeling parameters can be obtained in model calibration studies with the regional regression equations or available streamgage frequency curves.

Comparison of regional regression estimates and watershed model simulation of design storms might be used to judge the value of model parameters for areas smaller than 0.5 square miles (see recommended future studies).

2. Watersheds Below 7,000 feet:

The Corps performed watershed modeling calibration studies of observed historical storms including snowpack accumulation and melt (Cold Region Research and Engineering Laboratory, 2005) to develop recommended soil loss rates or effective loss rates that produce appropriate runoff rates for areas below 7,000 feet. These rates are important to hydrologic modeling near the lake elevation. Around the basin, modeling is complicated by 1) frozen ground (zero loss rates) 2) snowpack absorption of rainfall and 3) snowpack melt. The Corps has derived "effective loss rates" which take into account snowpack effects, thus negating the need to perform snowpack simulation as part of the hydrologic design process (refer Table 1).

Note: *The loss rates are used to produce an appropriate runoff rate when simulating design storm estimated from NOAA14. Basically, the loss rates were calibrated to account for the absorption of precipitation in the snow pack, snow melt, and soil rates. They are usually used as a surrogate for a runoff coefficient.*

Table 1: Recommended Constant Loss Rates (in/hr) for Open Areas Below 7,000 feet

Watershed	100-year Event (in/hr)	2-year Event (in/hr)
Upper Truckee	0.2	0.1
General	0.2	0.1
Ward	0.05	0.1
Incline	0.3	0.1
Third	0.3	0.1
Glenbrook	0.3	0.1
Trout	0.3	0.1

Note: *Interpolation and judgment can be used to determine loss rates for other locations and return periods. The above loss rates may not be representative of urban areas. Although, in undisturbed areas of an urban area (i.e., vacant, undeveloped parcel), the Table 1 loss rates can apply.*

There are no studies available which provide loss rates from snow-covered urban areas. The movement of snow by snowplows further complicates the issue. Undisturbed areas outside of roadways and other snow removal areas can be considered to exhibit the Table 1 loss rates.

For roadway surfaces and compacted shoulders where snow is stored, impervious cover conditions should be applied.

3. Drainage Areas < 200 acres

Runoff coefficient methods are recommended instead of watershed models for very small watersheds (< 200 acres) irrespective of the elevation. Gage information for these small basins does not exist. Consequently, ungaged analysis approaches accepted in professional practice were relied upon for the recommendations. Typically, the Rational Method is used in estimating design peak discharges for these small drainage areas. Unfortunately, published Rational Method coefficients are not particularly relevant to the snow-affected runoff in the Lake Tahoe Basin. In lieu of further studies, a conservative approach, with a runoff coefficient in the range 0.9 – 1.0, is suggested in applying the Rational Method. However, there is an issue that needs to be considered when modeling the effects of urban development (i.e., increasing the drainage area percent impervious). Under these circumstances, existing natural (forest and pasture) or previously landscaped drainage areas might be considered to have less runoff potential than the urbanized condition. Assuming less runoff potential would require a greater effort to mitigate the potentially increased runoff from the future development. Given the lack of data, this may require an operational decision by regulatory agencies. Future studies (see Section 3.3) might use watershed models to estimate the runoff coefficients for the Rational Method. Here, the information gained from the large watershed model calibration studies could be used to simulate the precipitation – runoff estimates needed to calibrate the runoff coefficients.

Use of watershed models such as HEC-HMS can be considered for small drainage areas (< 200 acres) to predict total storm runoff volumes and facilitate project design. Use of the loss rates indicated in Table 1 can be applied to pervious areas such as undeveloped, landscaped and open, undisturbed areas until further studies are completed.

The maximum basin size to use for application of this method depends largely on the variation in runoff properties and complexity of the drainage system in the area being analyzed. Estimating a composite runoff coefficient and the appropriate time of concentration for a drainage area becomes increasingly difficult as the drainage area contributions to runoff become more varied or distributed. The typical rule of thumb is to limit application to drainage areas less than 200 acres with relatively simple drainage patterns (e.g., no detention/retention storage).

4. Design Storms and Precipitation:

The NOAA 14 (NWS) precipitation depth-duration frequency curves should be used in estimating design precipitation in application with either the Rational Method or in creating design storms for watershed modeling studies. These precipitation frequency curves were found to be consistent with local Lake Tahoe basin gage data, although the user should be aware of the limitations of the results, given the lack of precipitation data for durations less than 60 minutes and elevations greater than 7000 feet (see SPK, 2006).

The Corps recommends a balanced design storm approach using NOAA 14 Atlas depth duration frequency curves. The effective loss rates shown in Table 1 were estimated so that model predictions with the design storms would produce runoff rates equivalent to that obtained simulating design storms using actual storm patterns (template events) (see Cold Region Research and Engineering Laboratory, 2005). The storm pattern simulations were used to estimate runoff for the 10yr and 100yr return interval for drainage less than 7000 feet. In these simulations, precipitation laps rates, snow melt dynamics and soil loss rates were considered. The effective loss rates in Table 1 combined with the NOAA14 balance design storms reproduce the runoff rates obtained from the detailed simulations performed with the “template events”. The combination of effective loss rates and design storms results in a practical method that can be used easily with available watershed models to estimate design runoff for drainage areas below 7000 feet.

Depth area reduction correction to the point estimates of precipitation will not be used because: 1) of the increase in precipitation with elevation; and, 2) the lack of studies analyzing the change in average storm depth with drainage area for the study area. Future studies of areal reduction factors by NOAA/NWS may result in recommendations for application of these reduction factors.

It should be noted that the recommended design storm should not considered conservative, as the loss rates were calibrated to produce runoff when simulating the design storms equal to the storm templates (i.e., storms based on patterns from actual major precipitation).

With regards to the consideration of depth area reduction factors, depth area reduction correction to the point estimates of precipitation are not recommended because: 1) of the increase in precipitation with elevation; and, 2) the lack of studies analyzing the change in average storm depth with drainage area for the study area. If this is desired, development of depth area corrections factors would be very difficult given the lack of data and orographic effects on precipitation. The corrections in older NOAA atlases are not very valuable, being based on TP40 for the eastern half of the U.S. Consequently, given that NOAA14 does not have these correction factors and that drainage areas are relatively small in the Tahoe Basin, development of any depth area correction factors is considered limited in value.

5. **Runoff routing (rainfall to runoff transform)**

For natural or open areas, use TR-55 (NRCS, 1986) methods including NRCS Lag Unit Hydrograph. Latest research indicates the use of 100 feet maximum length for sheet flow when computing time of concentration.

For urban areas, use Kinematic Wave overland flow panes including Muskingum Cunge channel routing.

6. **Channel Routing**:

Use Muskingum-Cunge routing method with standard roughness coefficients derived from TR-55 publication. As an alternative, one may use Muskingum routing method in reaches where travel time can be estimated.

3.3 Future Recommendations

The following future studies would provide additional information and guidance for estimating more accurate discharges for drainage design:

- Published coefficients for application of the Rational Method to small drainage areas (< 200 acres) are probably not relevant to the snow-affected runoff problem important to the Lake Tahoe basin. A watershed model simulation study, much as was done for the Placer County Manual (1990), using the results of the model calibration study (Cold Regions Research and Engineering Laboratory) could be performed to develop more appropriate coefficients.

- A national study (WRC, 1981) of flow-frequency curve estimation methods demonstrated that regional regressions were somewhat more accurate than simulation of design storms with watershed models in application to ungaged watersheds. Consequently, a future effort to develop guidelines for use of the Lake Tahoe basin regional regression equations (SPD, 2005a) to aid in watershed model calibration would improve model prediction accuracy.

- These future recommended studies can be incorporated into a comprehensive Tahoe Basin-specific drainage design manual if desired by SWQIC or other water quality/flood control stakeholders.

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