FACT SHEET NO. 2

Estimation of Surface Runoff

This fact sheet examines surface runoff processes and techniques used to estimate **total catchment runoff** and **peak flows generated by runoff** for small to medium sized 'non urbanised' catchments (< 250 km^2). Accurate estimation of these quantities depends on a large number of site characteristics. Hence it is not within the scope of this handbook to give precise techniques for every region in Australia. Instead, the general principles will be discussed and references provided to locate the information specific to a given region.

Runoff Processes

Losses: When rain falls on a catchment surface, a portion of it will be held back as 'losses' before the remaining 'excess rainfall' reports to streams or drainage channels as surface runoff. The losses combine a number of rainfall and interception mechanisms. In the early stages of a storm, much of the rain is intercepted by trees, grass and other plants and stored on leaves and branches etc. as **interception storage.** When these stores are full, water will reach the ground surface and commence filling small depressions. As these fill and overflow, large depressions begin to fill until this **depression storage** is full and overland flow commences. There are continuing losses through **infiltration** into the soil which starts at a high rate if the soil is initially dry and then rapidly decreases until approaching a steady rate known as the infiltration capacity of the soil. **Evaporation** from the vegetation and ground surfaces will also contribute to the losses. From this discussion it can be seen that losses (and hence rainfall excess) are affected by vegetation type and density, soil type and degree of disturbance, catchment slope and the number and efficiency of watercourses in the catchment.

Runoff types: Once losses have been absorbed there are two major runoff routes by which water reaches watercourses. In areas where soil is thinly overlying an impervious or rock layer, or where the groundwater level is very near the surface (eg. at valley bottoms or near streams) it will not take long to saturate the surface soil. Once this occurs, infiltration ceases and water will flow over the surface as **saturated overland flow.** Alternatively in sandy areas, or areas of deep permeable soil overlying impervious layers, water can rapidly flow downslope through the soil and percolate out of the soil when it intercepts a saturated zone. This is known as **interflow** and is differentiated from groundwater flow by the speed with which it reports to watercourses. The efficiency of these runoff processes is again dependant on soil types, as well as rainfall intensity, the geology of the area, catchment slopes and groundwater levels.

Design losses: When estimating total or peak runoff values it is necessary to estimate the losses, as it is only the rainfall excess which contributes to the runoff. With losses depending on so many site specific variables it is almost impossible to realistically model the processes. Even within a Single small catchment there will be a large number of sub areas responding differently due to varying physical characteristics. To simplify matters, a number of methods have been developed for applying general losses across a whole catchment.

A full discussion of these methods, along with typical loss values for regions throughout Australia can be found in Chapter 6 of *Australian Rainfall and Runoff 1987 (AR&R)*. The simplest and most popular of these methods are (refer to Figure FS 2.1):

(i) **Constant fraction (proportional losses/ runoff coefficients):** Loss is assumed to be a constant fraction of the rainfall. This can be viewed in two ways:

  a) A runoff coefficient (ie. 0.7) is applied to the rainfall. If a catchment large distinct areas (ie. undisturbed, stockpiles, sealed areas etc.) then a different coefficient can be applied to sub areas; and

Estimation of Surface Runoff

b) If a predictable proportion of the catchment is known to become saturated during rain then this area can be viewed as the proportion of the catchment contributing runoff.

(ii) **Constant loss rate:** If a catchment has minimal interception or depression storage and the infiltration into the soil is fairly constant (ie. if the catchment is already wet from previous antecedent rain) then a constant loss rate matching the infiltration capacity of the soil is a valid approach.

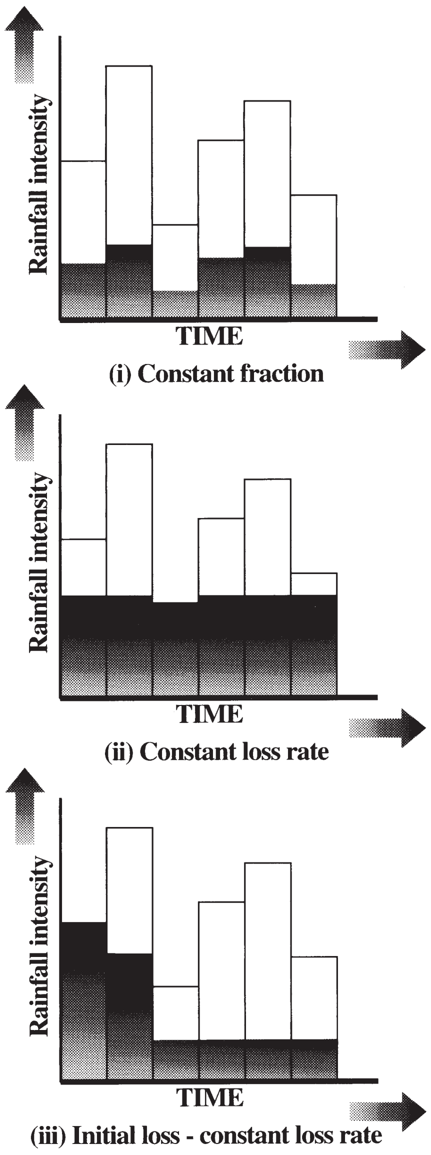
(iii) **Initial loss - constant loss rate:** In line with the above discussion of interception losses through vegetation and depression storage, followed by ongoing losses due to soil infiltration and evaporation, is the concept of having no runoff until an initial loss is satisfied and then having a constant loss rate for the remaining duration of the rain.

As well as *AR&R* there are many other sources of information for loss values applicable to an area:

- Consulting engineers/hydrologists;
- State government water resources departments;
- State government mining departments;
- State government agriculture/primary industries/forestry etc. departments;
- Local Landcare groups; and
- Local government engineers.

To obtain accurate estimates of losses it is important to note that there is no substitute for site measured data. A historical record of rainfall and streamflow (or dam levels, releases and overflows) will enable a hydrologist or engineer to develop much more accurate versions of the above loss models.

FIGURE FS 2.1 **Estimation of Surface Runoff**



FACT SHEET NO. 2

Estimation of Surface Runoff

Estimating Total Runoff

The total volume of runoff (saturated overland flow and interflow) from a catchment is important when examining overall site water balances or storage capacities required for water supply dams etc. The general procedure is to simply apply rainfall from the period of interest (eg. a single storm, a typical year or a long sequence of wet or dry years) to the catchment, subtract the appropriate losses as discussed previously and assume the excess rainfall reports as runoff to a stream, dam or pond. (The long-term processes of evaporation and seepage losses from a storage area must also be taken into account for long-period water balances.) The rainfall data required is discussed in Fact Sheet No. 10: Hydrological Data for Design Purposes. Computer programs are available for applying long-term daily rainfall records to a catchment, varying the loss values to suit historical stream flows or dam levels. These can be used for projecting catchment yields into the future to examine water storage and recycling opportunities. One such model gaining popularity in Australia is the AWBM model.

Estimating Peak Flows

As discussed throughout this handbook, interception drainage, erosion protection, settling ponds and essential drainage infrastructure (eg. culverts, spillways etc.) must all be carefully designed to suit the expected peak flow they are expected to experience. A confident estimate of this flow is essential to:

a) prevent under designing drainage infrastructure, which may result in damage and hence disruptions to mine operations and ongoing repair and upgrade works; and

b) avoid over designing, which is of course uneconomical.

Detailed discussions of estimation procedures can be found in *AR&R*. For typical mine catchments, the best method to obtain a quick estimate is the **rational method** which is of the form:

$Q_Y = 0.278.\ C_Y.\ I_{tc,\ Y}\ .\ A$ (Eqn 5.1 *AR&R*)

where

- Q_Y = Peak flow rate (m^3/s) of average recurrence interval (ARl) of Y years
- C_Y = Runoff coefficient (dimensionless) for ARI of Y years
- A = Area of catchment (km^2)
- $I_{tc,\ Y}$ = Average rainfall intensity (mm/h) for the design duration of t_c hours and ARI of Y years.

The way to use the rational method is as follows:

- first decide on the appropriate risk level, hence selecting the average recurrence interval of storm to be used (refer to Fact Sheet No.3);
- the duration of storm to give the worst flood is then selected. The principle here is that the shorter the storm the higher the intensity will be for a given ARI. However, if too short a time is used then runoff from far reaches of the catchment will not have had a chance to contribute to the flow. Hence the critical duration, known as the time of concentration t_c, is selected as the time required for the most remote part of the catchment to begin contributing to runoff at the point of interest. Different methods for calculating t_c are presented in *AR&R* for various regions in Australia. Most of these depend on stream lengths and typical catchment slopes;
- determine the average rainfall intensity (mm/hour) associated with the selected ARI and $t_{c.}$ Intensity; duration, and frequency rainfall curves for the specific minesite will be required. These can be developed using guidelines in *AR&R* or can be obtained through the Bureau of Meteorology.

They will simply need the longitude and latitude of the minesite (refer to Fact Sheet No. 10);

- calculate the runoff coefficient for the site using the methods defined in *AR&R* for each region within Australia, or if available using values developed for your specific area and type of land use. (Neighbouring mines, land care groups, soil conservation departments or universities involved in runoff management in your area may have previously developed such coefficients); and
- measure the plan area (km^2) of the catchment feeding into the point of interest, taking into account pits, diversion drains, ridges etc.

Having obtained all the above information, it can be used in the previous equation to give the peak flow.

Probable Maximum Flows (PMF)

When designing spillways on large dams or examining major flood mitigation works where lives may be at risk, it is usually wise to use the maximum possible flow rate. This will ensure that the given element is unlikely to ever fail. Due to the importance of such calculations, experienced engineers or hydrologists should be consulted before using these flows for design purposes.

Before it is possible to calculate peak flows, it is necessary to determine the **probable maximum precipitation** for the given area. For small areas and short-duration storms the Bureau of Meteorology has published an upgraded method of calculating PMP in Bulletin 53 (December 1994) *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method.* For larger areas or long storms, the Bureau will provide estimates of PMP for a set charge.

Once the PMP is determined, small losses are applied to determine the rainfall excess. The losses will be small due to the high likelihood of antecedent rainfall. It is suggested that values of zero or slightly below the lowest specified loss values for the area can be used. Having determined the rainfall excess, it is then a matter of using methods as described above, or more complex flood routing techniques (depending on catchment size and complexity) to determine the probable maximum flow (PMF). Section 13.4 of *AR&R* gives basic descriptions of the techniques used in such calculations.