BASIC PRINCIPLES

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This information was prepared for the general use of staff, Town Board members, Planning Commission members, contractors, developers and other interested parties. Its purpose is to provide some aid in the understanding of the basic principles behind drainage regulation and to insure compliance with its intent.

HISTORIC (OR UNDEVELOPED)

Under natural or undeveloped conditions, rainfall will collect towards the swales generally already existing within each topographical area.

These swales convey their accumulating flows towards larger collectors such as gullies, ditches and finally, rivers.

The amount of flow conveyed by this naturally existing collector system obviously is in direct proportion to the size of the area, the amount of rainfall deposited and the time required to collect and convey the accumulating flows.

Let's assume for a moment that a rainstorm is occurring in the geographical area in which we are interested. Selecting a convenient collector point downstream from the area under investigation, such as a major culvert under an existing road, we notice the following.

It takes a certain amount of time for the individual raindrops to travel and collect on a natural surface consisting of pervious soil, possibly covered with native vegetation of various densities and consequently, the culvert will be standing dry for a certain period of time.

After a while, the first flows begin to arrive. First a slow trickle that increases both in volume and velocity until, after a given period of time, a maximum volume and velocity is reached. This moment is called the <u>peak flow</u>. Its magnitude is expressed in Cubic Feet per Second (C.F.S.). Meanwhile the rainstorm is beginning to decrease in intensity and will finally stop. Shortly thereafter, both volume and velocity of the water conveyed by the culvert will decrease until all of the rainstorm <u>volume</u> has been conveyed.

In analyzing our observations, we first note that the existing culvert was flowing full or even slightly submerged at the moment of peak flow. Assuming that the culvert was sized in accordance with currently prevailing drainage criteria, we can deduce that the observed rainstorm was of an intensity commonly known as the major storm. In order to fully appreciate the term major storm, we should be aware of the following.

To predict the magnitude and frequency of rainstorms, a large number of rain gage stations collect data over an extended period of time. Since the accuracy of the prediction will increase with time, this data collection process is continuous.

By means of the statistical data collected in this manner, it becomes possible to establish for each geographical region and with ever-increasing accuracy, how many inches of rainfall can be expected from a rainstorm of such a size that it occurs, on the average, only once in a certain period of years.

The size of these rainstorms is consequently graded by the average period of time in which their intensity occurs. For example, a 10-year storm is of such a magnitude that it occurs on an average of once every ten years. It can also be expressed by saying that it has a 10% chance of occurring during a single year.

Major drainage structures accommodating the accumulated drainage of a geographical area must necessarily be capable of conveying and controlling fairly substantial volumes of water. Structures of this nature must consequently be capable of conveying the flows generated by a major storm.

The magnitude of such a major storm should be such that potential flooding and associated hazards occur only when its selected magnitude is exceeded, and at associated fairly large time intervals. Yet, the selected storm should not be of such a magnitude that the resultant drainage control structures become excessive both in size and cost. The most widely accepted compromise that has virtually become the standard is the 100-year storm.

Assuming that the culvert under observation was designed to carry the peak flow generated by the standard major storm while flowing full or slightly submerged, it is fairly probable that said storm was of the standard 100-year magnitude. The only reason that this is by no means a certainty is that older or more lenient requirements sometimes allowed the use of the 50-year or even the 25-year storm as the design parameter.

Assuming, however, that the observed storm was of the 100-year variety, we also noted several associated items of interest.

As the volume of water conveyed by the existing collector system increased, the water surface increased proportionately both in depth and in area being submerged. After reaching a maximum depth and area of inundation, water surface elevations commenced to decline again. For a storm of the 100-year magnitude, the bounding limits established by this maximum area of inundation are commonly known as the 100-year flood plain.

Permanent structures within the 100-year flood plain area are generally not allowed. Similar restrictions are applied to proposed modifications that would increase the water elevation, area of inundation or flow velocity.

In general, where major streams and rivers are involved, exemptions can only be granted by the County, State or Federal agency under whose jurisdiction the pertaining flood plain falls. Such modifications are neither common nor readily granted. There are regulated procedures which allow for correction or modification of the already-existing flood plain maps, which are strictly regulated by the Federal Emergency Management Agency (FEMA). It should be noted that such exemptions are rarely granted. It should also be noted that there are some generally-accepted uses allowed within these flood plain areas: such as parks, tennis courts, athletic fields, among others.

The main reasoning behind these rather stringent limitations is mostly based on two major considerations. There is, first of all, the general philosophy that tampering with the natural 100-year "safety valve" area provided by nature itself over thousands of years, generally produces some rather unpleasant side effects, such as an increase in flow velocities and erosion, or an increase in the area being inundated by the 100-year storm. For example, existing developments that were well outside the 100-year flood plain suddenly might find themselves to be part of one. In that respect, such tampering with the 100-year flood plain could have too many wide-ranging effects on both the upstream and downstream areas.

A secondary reason is provided by the reluctance of insurance companies to provide coverage on dwelling units that, on a yearly basis, have a 1% probability of suffering major damage. In view of this, it is understandable that most 100-year flood plain maps and data are provided in Flood <u>Insurance</u> Studies by the Federal Emergency Management Agency and the Federal <u>Insurance</u> Administration (FIA).

It should now be fairly clear on what basis the 100-year storm frequency was selected as the parameter for the design of the <u>major</u> drainage collector system.

As will be discussed later, development generally does have a significant and potentially undesirable impact on the 100-year peak flow. In addition, type and extent of both existing and future developments responsible for such peak flow increases are highly unpredictable. The use of potentially variable developed peak flows of uncertain magnitudes is therefore obviously undesirable for drainage design purposes. A more stable parameter is provided by the undeveloped condition. The parameter for the design of the major drainage collector system will therefore be the 100-year undeveloped (or historic) peak flow. This storm is henceforth known as the major storm.

Some inconsistency may be encountered in areas where development historically already has taken place prior to the adoption and enforcement of these drainage regulations. Since it is both impractical and probably impossible to enforce such drainage regulations retroactively, peak runoff from these areas is assumed to be "historic".

In analyzing the potential impact of development on the 100-year undeveloped peak flows, we notice the following. Under both the developed and undeveloped conditions the volume of rainwater deposited during the 100-year storm is basically unchanged. We do note, however, that there is generally a significant change in the magnitude of the resultant peak flows. Due to existing natural soils conditions and vegetation, the undeveloped conveyance of this volume of water is generally spread out over a longer period of time.

The replacement of these natural surface conditions with substantial areas of concrete, asphalt and roofs obviously increases surface flow velocities and, therefore, almost invariably results in much shorter periods of time in which the surface runoff accumulates. That such velocity increases significantly impact the peak flow can be more easily understood if one pictures the system as a giant faucet.

There are two basic approaches in which an imaginary 100-gallon container can be filled from this faucet. In the first approach, water is flowing from its orifice at a rate of only 1 gallon per minute. The 100-gallon container will consequently be filled after a period of 100 minutes.

In the second approach, water is flowing from its orifice at a rate of 10 gallons per minute. The same 100-gallon container will now be filled after only 10 minutes.

In reviewing the above approaches, it is noted that the same 100-gallon volume was conveyed. However, in the second approach this conveyance occurred at 10 times the velocity and consequently in 1/10th the period of time. In other words, its peak flow was 10 times greater.

The impact on a drainage collector system is similar. The same volume of water from the same major storm is conveyed by the system. However, under developed conditions, flow velocities and peak flows usually increase significantly.

This is obviously undesirable since substantial flow velocity increases make it necessary to implement extensive erosion and damage control systems.

It should also be remembered that the naturally existing major collector system was capable of conveying the 100-year undeveloped peak flows. This existing system is quite often incapable of conveying the increased developed peak flows and substantial flooding or associated damage could result. In addition, the conveyance of increased peak flows would almost certainly result in higher water surface elevations and subsequently increase the 100-year flood plain area. As previously discussed, such flood plain expansions are highly undesirable. To avoid the occurrence of these conditions, the 100-year detention requirement was developed.

The rainfall runoff from each new development is routed into a selected ponding site prepared for that purpose. On the downstream side of the ponding area, a depressed section generally allows for the overflow of storms in excess of the 100-year event.

Such a "detention" pond is also sized in such a manner that during the 100-year storm, surface water elevations will rise to a maximum level just below the overflow. During this process, a sized pipe is discharging flows at moderate velocities and at a magnitude that at no time exceeds the **historic** or **undeveloped** peak flow established and allowed for in the pertaining development area. In addition the outflow control structure contains a sized outflow which restricts the design storm discharge (see next page), to historic levels or less. Shortly after termination of the pertaining storm such a "detention" pond area is standing dry again.

For large developments, park and landscaping areas are quite often used as detention ponds. With smaller developments, parking lots are often designed in such a manner that they would satisfy these detention requirements.

By these relatively simple means, overall velocities and peak flows are maintained at approximate undeveloped levels or less.

For analysis and design of the primary drainage system, The Town of Bennett designated the 100-year frequency storm. This storm frequency is henceforth known as the major storm.

The conveyance of the 100-year storm within towns and cities is fairly well regulated. The magnitude of inundation allowed on streets conveying major flows is determined in accordance with their respective primary importance as vehicular traffic lanes. In addition, adjacent buildings are generally required to be well outside the maximum area of flooding allowed for these streets. It's important to note that storms of the 100-year magnitude are not very common and some preventative drainage design should allow for the alleviation of more frequently occurring problems during lesser storms.

For a certain magnitude of storm, it is required that sidewalks, driveways and similar structures remain accessible while minimum grades, secondary collector swales and other preventative drainage measures should insure relief from the potential inconveniences associated with such lesser storms.

Peak flows generated by such a storm are collected by a secondary system that insures immediate local drainage. Although the accumulated runoff from the secondary system is eventually conveyed by the primary system, the parameters for its design are based on storms of a lesser magnitude.

Based on economic considerations, the storm selected by the Town of Bennett to that purpose is the 10-year frequency storm. This storm frequency is henceforth known as the **design storm**.

Based on the design storm parameters, structures such as gutters would be required to carry the associated 10-year peak flow without curb overtopping. Whenever such accumulating 10-year peak flows exceed the available curb and gutter capacity, inlets and their associated storm sewer collector systems shall be installed, thereby insuring the accessibility of the sidewalks up to storms of a 10-year magnitude.

Design for all pertaining ditches, culverts and other associated structures within this secondary collector system should also be based on the parameters provided by the 10-year design storm.

Since there is some overlap between the two systems, it becomes necessary to define more clearly the area in which each design parameter is applicable. For that purpose, the following guideline shall be adhered to.

All facilities conveying in excess of 300 cubic feet per second as a result of the 100-year event shall be designed in compliance with the major storm parameters. The design of all other facilities shall be based on the 10-year design storm event.

A fairly large number of procedures for calculating peak design flows have been developed throughout the years. By far the most widely known are the "Rational Method", the "Urban Hydrograph Method" and the "Soils Conservation Service Method".

For drainage basins that are not complex and have generally 160 acres or less, it is preferred that the design storm runoff be analyzed by the Rational Method.

For basins that are larger than 160 acres, it is recommended that the design storm runoff be analyzed by means of the "Colorado Urban Hydrograph Procedure ".

For basins in excess of 160 acres and containing large areas of undeveloped and/or farm land, analysis by means of the "Soils Conservation Service Method" is acceptable.

Unless waived in writing by the Town Engineer or designated Town representative, the Town of Bennett requires detention of both the 10-year and 100-year storm events with associated allowable release rates at historical levels or less. Unit release rates based on existing soil types are acceptable to determine the allowable historic release rates.

For determining the required detention volumes, the Federal Aviation Administration (FAA) procedure is strongly recommended.

Storage structures with embankment heights in excess of 10 feet, storage volume greater than 1,000 acre-feet, or a surface area in excess of 20 acres fall under the regulations of the State of Colorado Division of Water Resources. These structures will be designed on a more stringent standard which, dependent on an assigned hazard rating, may be a probable maximum precipitation or approximately four times the 100-year precipitation.

In conclusion, it should be known that all rainfall data was either directly or indirectly derived from the NOAA Atlas for Colorado and the Adams County Storm Drainage Criteria Manual.