3. An elevation certificate is required to be submitted to the Floodplain Administrator and deemed acceptable prior to obtaining a Certificate of Occupancy for the building. It is advised to follow-up with a LOMR-F or LOMA to remove the building from the flood zone.

22.6 Downstream Capacity and Offsite Flows

Downstream capacity and offsite flows are the most important elements of a successful drainage report/plan. The engineer is expected to research adjacent projects, as-built storm drain construction plans and Drainage Master Plans to correctly identify downstream capacity. See the Valley Drainage Criteria section if the project is in the valley.

The engineer is also expected to perform a site visit, review topography and review adjacent drainage reports/plans to accurately identify offsite flows.

22.6.1 The drainage report/plan shall accurately state allowable downstream capacity. In the case, where the project is a small redevelopment project (less than 0.5 acres) and not in the valley, proposed flows not to exceed historic flows is most likely acceptable. Some small sites may have a history in which proposed flows may have to be less than historic flows.

22.6.2 The drainage report/plan is to show the location and quantify offsite flows. In general, sites are to except offsite flows and convey them safely to an acceptable outfall. A site may not have to accept offsite flows if a previously approved plan shows the outfall adjacent to the site and flows can be safely conveyed to an acceptable outfall.

22.6.3 If the only reasonable outfall for a proposed development is a historic flow path through an adjacent private property, the historic flow characteristics and path must be maintained.

22.7 Engineered Channels and Natural Arroyos

1. General Hydraulic Criteria

In general, all open channels should be designed with the tops of the walls or levees at or below the adjacent ground to allow for interception of surface flows. If it is unavoidable to construct the channel without creating a pocket, a means of draining the pocket must be provided on the drawings. All local drainage should be completely controlled. External flows must enter the channel at designated locations and through designated inlets unless specifically otherwise authorized by the City Engineer.

2. Sharp Curves

In making preliminary layouts for the routing of proposed channels, it is desirable to avoid sharp curvatures, reversed curvatures, and closely-spaced series of curves. If this is unavoidable, the design considerations in Section C-3 below must be followed to reduce superelevations and to eliminate initial and compounded wave disturbances.

3. Maximum Froude Number

It is generally desirable to design a channel for a Froude number of just under 2.0. In areas within the City of Albuquerque this is not always possible because of steep terrain. If the Froude number exceeds 2.0, any small disturbance to the water surface is amplified in the course of time and the flow tends to proceed as a series of "roll waves". Reference is made to Section C-3 for criteria when designing a channel with a Froude number that exceeds 2.0.

In the design of a channel, if the depth is found to produce a Froude number between 0.7 and 1.3 for any significant length of reach, the shape or slope of the channel should be altered to secure a stable flow condition. All analyses should be performed for the 10-year and 100-year design discharges.

4. Water Surface Profile Calculations

a. General

Water surface profile calculations must be calculated using the Bernoulli energy equation combined with the momentum equation for analyzing confluences and functions.

b. Determination of Controlling Water Surface Elevation

The following are generally control points for the calculation of the water surface profile:

(1) Where the channel slope changes from mild to steep or critical, the depth at the grade break is critical depth.

(2) Where the channel slope changes from critical to steep, the depth at the grade break is critical depth.

(3) Where a discharging channel or conduit is on a mild slope, the water surface is generally controlled by the outlet.

(4) When a channel on a steep slope discharges into a facility that has a water surface depth greater than the normal depth of the channel, calculate pressure plus momentum for normal depth and compare it to the pressure plus momentum for the water surface depth at the outlet according to the equation, $P_n + M_n \sim P_o + M_o$.

(a) If $P_n+M_n > P_o+M_o$, this indicates upstream control with a hydraulic jump at the outlet.

(b) If $P_n + M_n < P_o + M_o$, this indicates outlet control with a hydraulic jump probably occurring upstream.

(c) Where the water surface of the outlet is below the water surface in the channel or conduit, control is upstream and the outflow will have the form of a hydraulic drop.

When there is a series of control points, the one located farthest upstream is used as a starting point for water surface calculation.

c. Direction of Calculation

Calculations proceed upstream when the depth of flow is greater than critical depth and proceed downstream when the depth of flow is less than critical depth.

d. Head Losses

(1) Friction Loss

Friction losses or open channels shall be calculated by an accepted form of the Manning equation. The Manning equation is commonly expressed as follows:

$$Q = \frac{1.486}{n} A R^{2/3} S_f^{1/2}$$

Where:

Q = Flow rate, in c.f.s.

n = Roughness coefficient

A = Area of water normal to flow, in ft.2

R = Hydraulic radius

S_f = Friction slope

When arranged into a more useful form,

$$Sf=(2gn^2/2.21((V^2/2g)/R^{4/3})$$

The loss of head due to friction throughout the length of reach involved (L) is calculated by:

$$h_f = S_f L$$

Refer to the appendix for values of "n" for different materials and corresponding values of:

$$\frac{2gn^2}{2.21}$$

(2) Junction Loss

Junction losses will be evaluated by the pressure plus momentum equation and must conform to closed conduit angle of confluence criteria, Section B-5. Refer to Miscellaneous Hydraulic Calculations later in this section.

e. Channel Inlets

(1) Side Channels

Flow rates of 25% or more of the main channel flow must be introduced to the main channel by a side channel hydraulically similar to the main channel. The centerline radius of the side channel may not be less than the quantity (QV/l00) in feet.

Velocity and depth of the flows in the side channel when introduced into the main channel must be matched to within 1 foot of velocity head and to within 20% of the flow depth for both the 10-year and l00-year design discharges and the four combinations of side inlet and main channel flows which result. Energy and momentum balance type calculations must be provided to support all designs involving side channels.

(2) Surface Inlets

When the main channel is relatively narrow and when the peak discharge of side inflow is in the range between 3 and 6 percent of the main channel discharge, high waves are usually produced by the side inflow and are reflected downstream for a long distance, thus requiring additional wall height to preclude overtopping of the channel walls. This condition is amplified when the side inflow is at a greater velocity than the main channel. To eliminate these wave disturbances, the Los Angeles District of the Corps of Engineers has developed a side channel spillway inlet. The City or AMAFCA may require this type of structure when outletting into one of their facilities, and its use should be considered for city channels if high waves above the normal water surface cannot be tolerated. See Subsection "f" below titled "Transitions" for the Corp's procedure and criteria.

Surface-type inlets shall be constructed of concrete having a minimum thickness of 6 inches and shall be reinforced with the same steel as 6" concrete lining. The upstream end of the surface inlet shall be provided with a concrete cutoff wall having a minimum depth of three feet and the downstream end of the inlet shall be connected to the channel lining by an isolation joint. Side slopes of a surface inlet shall be constructed at slopes no greater than l vertical to 10 horizontal to allow vehicular passage across the inlet where a service road is required.

Drainage ditches or swales immediately upstream of a surface inlet shall be provided with erosion protection consisting of concrete lining, rock riprap or other non-erosive material.

Surface inlets shall enter the channel at a maximum of 90o to the channel centerline, i.e., they may not point upstream.

(3) Direct Pipe to Channel

Junctions involving direct pipe connection to a channel must conform to the criteria listed in Section 5 of the closed conduit criteria. Additionally, pipe and box culvert inlets to channels shall be isolated by expansion joints. Continuously reinforced channels shall be designed to accommodate any extra stress resulting from these discontinuities. Paragraph 18(h), Corps of Engineers EM 1110-2-1061 has additional design criteria.

f. Transitions

(l) Subcritical Flow

For subcritical velocities less than 12 f.p.s., the angle of convergence or divergence between the center line of the channel and the wall must not exceed 12o 30'. The length of the transition (L) is determined from the following equation:

$$L \geq 2.5 \, \Delta B$$

For subcritical velocities equal to or greater than 12 f.p.s., the angle of convergence or divergence between the center line of the channel and the wall must not exceed 5o 45'. The length (L) is determined from the following equation:

$$L \geq 5.0\ \Delta B$$

Head losses for transitions with converging walls in subcritical flow conditions can be determined by using either the P + M method or the Thompson equation, both of which are shown in Section 22.8. For transitions, both methods are applicable in all cases and will give the same results.

(2) Supercritical Flow

(a) Divergent Walls

The angle of divergence between the center line of the channel and the wall must not exceed 5^{O} 45' or $\tan^{-1}(F/3)$ whichever is smaller. The length of the transition (L) is the longest length determined from the following equations:

$$L \geq 5.0\ \Delta B$$

$$L \geq 1.5\ \Delta B*F$$

Where:

F = Upstream Froude number based on depth of flow

Δ B = The difference in channel width at the water surface

(b) Convergent Walls

Converging walls should be avoided when designing channels in supercritical flow; however, if this is impractical, the converging transition will be designed to minimize wave action. The walls of the transition should be straight lines.

(3) Transitions Between Channel Treatment Types

(a) Earth Channel to Concrete Lining Transition

The mouth of the transition should match the earth channel section as closely as practicable. Wing dikes and/or other structures must be provided to positively direct all flows to the transition entrance.

The upstream end of the concrete lined transition will be provided with a cutoff wall having a depth of 1.5 times the design flow depth but at least 3.0 feet and extending the full width of the concrete section. Erosion protection directly upstream of the concrete transition consisting of grouted or dumped rock riprap at least 12 feet in length and extending full width of the channel section must be provided. Grouted riprap must be at least 12 inches thick and tied to the concrete lining and cutoff wall. Dumped riprap must be properly sized, graded and projected with gravel filter blankets.

The maximum allowable rate of bottom width transition is 1 to 7.5 maximum. Grout, dumped, or wire-tied material may also be used if approved on a case-by-case basis by the City Engineer. Grouted and wire-tied material require gravel filters as well.

(b) Concrete Lining to Earth Channel Transition

The transition from concrete lined channels to earth channels will include an energy dissipator as necessary to release the designed flows to the earth channel at a relatively non-erosive condition.

Since energy dissipator structures are dependent on individual site and hydraulic conditions, detailed criteria for their design is included in the section Criteria for Hydraulic Design of Closed Conduits. Minimum requirements are included herein for the concrete to earth channel transition.

On this basis, the following minimum standards govern the design of concrete to earth channel transitions:

Maximum rate of bottom width transitions:

Water Velocity	
0-15 f.p.s	1:10
16-30 f.p.s.	1:15
31-40 f.p.s.	1:20

The downstream end of the concrete transition structure will be provided with a cutoff wall having a minimum depth of 4 feet and extending the full width of the concrete section.

Directly downstream of the concrete transition structure erosion protection consisting of rough, exposed surface, grouted rock riprap and extending full width of the channel section shall be provided. The grouted rock riprap should be a minimum of 12 inches thick and tied to concrete structure and the cutoff wall. Grout, dumped, or wire-tied material may also be used if approved on a case-by-case basis by the City Engineer. Grouted and wire-tied material require gravel filters as well. Riprap design criteria is presented in Section 9.

F. Bank Protection

All berms and levees expected to convey or divert 30 cfs or more in the event of the 100-year design discharge must be provided with bank protection according to the following guidelines:

a. Bank protection must be provided wherever design velocities exceed 5 feet/sec.

b. Bank protection must be provided on the outside of curves from the beginning of curvature, through the curve and for a distance equal to 5 times the flow velocity in feet downstream from the point of tangency.

c. When required, bank protection must be provided to two feet above the design flow depth plus additional depth as required (e.g. superelevation, waves at confluences, hydraulic jumps, etc.).

d. Bank protection must extend downward on a projection of the bank slope, to a minimum depth equal to 1.5 times the design flow depth but never less than 3.0 feet. Bank protection for major arroyos shall be accompanied by a City Engineer approved sediment transport analysis.

NOTE: *Berms, dams, levees, and diversions of certain magnitudes and nature may fall within the jurisdiction of the State Engineer of the State of New Mexico. The design professional is expected to be aware of and comply with regulations promulgated by that jurisdiction*.

g. Piers

The effect of piers on open channel design must be considered at bridge crossings and where an open channel or box conduit not flowing full discharges into a length of multi-barreled box. This effect is especially important when flow is supercritical and when transported debris impinges on the piers.

The total pier width includes an added width for design purposes to account for debris. Inasmuch as the debris width to be used in design will vary with each particular situation, the City Engineer will be contacted during the preliminary design stages of a project for a determination of the appropriate width. Streamline piers should be used when heavy debris flow is anticipated. Refer to Section 22.8 for design data regarding streamline piers.

The water surface elevations at the upstream end of the piers is determined by equating pressure plus momentum. The water surface profile within the pier reach is determined by the Bernoulli equation. The water surface elevations at the downstream end of the piers may be determined by applying either the pressure plus momentum equation or the Bernoulli equation.

H. Curving Alignments

a. Superelevation

Superelevation is the maximum rise in water surface at the outer wall above the mean depth of flow in an equivalent straight reach, caused by centrifugal force in a curving alignment.

(1) Rectangular Channels

For subcritical velocity, or for supercritical velocity where a stable transverse slope has been attained by an upstream easement curve, the superelevation (s) can be calculated from the following equation:

$$S = \frac{V^2 b}{2g r}$$

For supercritical velocity in the absence of an upstream easement curve, the superelevation (S) is given by the following equation:

$$S = \frac{V^2 b}{2g r}$$

where:

V = velocity of the flow cross section, in f.p.s.

b = Width of the channel, in ft.

g = Acceleration due to gravity

r = Radius of channel center line curve, in ft.

X = Distance from the start of the circular curve to the point of the first S in ft.

D = Depth of flow for an equivalent straight reach

B = Wave front angle

where $X=(\pi bV)/((12gD)^{0.5})$

"S" will not be uniform around the bend but will have maximum and minimum zones which persist for a considerable distance into the downstream tangent.

(2) Trapezoidal Channels

For subcritical velocity, the superelevation (S) can be calculated from the following equation:

$$S = 1.15V^2 (b + 2 z D) / 2 g r$$

Where:

z = cotangent of bank slope

b = channel bottom width, in ft.

For supercritical velocity, curving alignments shall have easement curves with a superelevation (S) given by the following equation:

$$S = 1.3V^2 (b + 2 z D) / 2 g r$$

(3) Unlined Channels

Unlined channels will be considered trapezoidal insofar as superelevation calculations are concerned. However, this does not apply to calculations of stream or channel cross-sectional areas.

b. Easement Curves

Easement curves are alignment transition curves, employed upstream and downstream of circular curves, when supercritical flow exists in open channels. The purpose of the easement curve is to alter the transverse slope of the water surface and keep the water prism in constant static equilibrim against centrifugal force throughout the entire length of the easement curve and central circular curves, thus achieving minimum heights of superelevation with avoidance of cross-wave disturbances.

Circular easement curves are recommended in lieu of spiral transition curves for each of design and construction. Also very little hydraulic advantage is gained by the use of the spiral. The circular easement curve consists of curved sections upstream and downstream of the main curve having a radius (2R), twice the main curve radius (R).

(1) Conditions Requiring Easement Curves

(a) When the freeboard, above superelevated water surface (as calculated without an easement curve), is less than two feet.

(b) In reverse curves or on alignments where curves follow one another closely.

(c) For any case where elimination of cross-wave disturbances is required. (If easement curves are not used, additional freeboard downstream of the curve may be necessary).

(d) In trapezoidal channels for all cases of supercritical velocity.

(2) Length of Easement Curve

For rectangular channels, the length of easement curve (L_E) is given by the following equation:

$L_E = 2X = 0.32bVD^{0.5}$

For trapezoidal and associated channel types, the length of easement curve (L_E) can be calculated as follows:

$L_E = 0.32(b+2zD)VD^{0.5}$

Refer to the section on superelevation above for the definition of terms.

4. Freeboard

Freeboard is the additional wall height applied to a calculated water surface.

a. Rectangular Channels (not used except with City Engineer approval)

(1) For flow depths of 1.0 feet or less and average flow velocities less than 35 f.p.s., add l.0 feet.

(2) For flow depths of 1.0 feet or less and average flow velocities greater than 35 f.p.s., add 1.5 feet.

(3) For flow depths of greater than l.0 feet and average flow velocities of less than 35 f.p.s., add 2.0 feet.

(4) For flow depths of greater than 1.0 feet and average flow velocities of greater than 35 f.p.s., add 3.0 feet.

(5) For supercritical flow where the depth is between D_C and 0.80 DC, the wall height must be equal to the sequent depth, but not less than the heights required above. This condition should be avoided.

(6) Freeboard requirements for concrete drainage easement channels shall be established by the City Engineer on a case-by-case basis.

b. Trapezoidal Channels and Associated Types

Adequate channel freeboard above the designed water surface must be provided and will not be less than determined by the following:

(l) For flow rates of less than 100 c.f.s. and average flow velocity of less than 35 f.p.s.:

Freeboard (Feet) = $1.0 + 0.025Vd^{1/3}$

(2) For flow rates of 100 c.f.s. or greater and average flow velocity of 35 f.p.s. or greater:

Freeboard (Feet) = $0.7\ (2.0 + 0.025Vd^{1/3})$

Freeboard will be in addition to any superelevation of the water surface, standing waves and/or other water surface disturbances. When the total expected height of disturbances is less than 0.5 feet, disregard their contribution.

Unlined portions of the drainage way may not be considered as freeboard unless specifically approved by the City Engineer.

For supercritical flow where the specific energy is equal to or less than 1.2 of the specific energy at D_c, the wall height will be equal to the sequent depth, but not less than-the heights required above. This condition should be avoided.

c. Roll Waves

Roll waves, sometimes known as slug flow, are intermittent surges on steep slopes that will occur when the Froude Number (F) is greater than 2.0 and the channel invert slope (S_0) is greater than the quotient, twelve divided by the Reynolds Number. When they do occur, it is important to know the maximum wave height at all points along the channel so that appropriate wall heights may be determined based on the experimental results of roll waves by Richard R. Brock, the maximum wave height can be estimated.

5. Channel Design Criteria

a. Unlined Channels

After full consideration has been given to the soil type, velocity of flow, desired life of the channel, economics, availability of materials, maintenance and any other pertinent factors, an unlined earth channel may be approved for use.

Generally, its use is acceptable where erosion is not a factor and where mean velocity does not exceed 3 f.p.s. Old and well-seasoned channels will stand higher velocities than new ones; and with other conditions the same, deeper channels will convey water at a higher nonerodible velocity than shallower ones. Additional information is provided in Section 22.8.

Maximum side slopes are determined pursuant to an analysis of soil reports. However, in general, slopes should be 3:1 or flatter.

b. Composite Linings

In case part of the channel cross section is unlined or the linings are composed of different materials, a weighted coefficient must be determined using the roughness factors for the materials.

c. Maximum Sidewall Slopes

The following sidewall slopes are generally the maximum values used for channels on at least one side of the concrete lined channel. The road should be sloped away from the channel, and roadway runoff carried in a controlled manner to the channel.

Lining Material	Maximum Slope
Soil Cement	2:1
Portland Cement Concrete	Vertical (Trapezoidal 2:1)
Grouted Rock Rip-Rap	2:1
Dumped Rock Rip-Rap	2:1
Earth Lined	3:1
Grass Lined (sodded)	4:1

d. Channel Maintenance and Access Road

A maintenance and access road having a minimum of 12 feet top width shall be provided on at least one side of improved channels. In some cases the City Engineer may require additional width. Channel maintenance and access roads shall be surfaced with gravel base course. The thickness of said base course shall be 6 inches west of the Rio Grande, 4 inches east of the Rio Grande.

Turnouts will be provided at no more than ½ mile intervals and turnarounds must be provided at all access road dead ends.

Ingress and egress from public right-of-way and/or easements to the channel maintenance and access road must be provided.

e. Channel Access Ramps

Channel access ramps for vehicular use will be provided as necessary for complete access to the channel throughout its entire length with the maximum length of channel between ramps being one-half mile.

Ramps shall be constructed of 8" thick reinforced concrete and will not have slopes greater than 17% and ramps shall not enter the channel at angles greater than 15o from a line parallel to the channel centerline.

Ramps will be constructed on the same side of the channel as the maintenance and access road. The maintenance and access road shall be offset around the ramp to provide for continuity of the road full length of the channel.

The downhill direction of the ramp should be oriented downstream.

f. Street Crossings

Street crossing or other drainage structures over the concrete lined channel should be of the all weather type, i.e., bridges or concrete box culverts. Crossing structures should conform to the channel shape in order that they disturb the flow as little as possible.

It is preferred that the channel section be continuous through crossing structures. However, when this is not practicable, hydraulic disturbance shall be minimized, and crossing structures should be suitably isolated from the channel lining with appropriate joints.

Street crossing structures shall be capable of passing the l00 year frequency design storm flows.

Channel lining transitions at bridges and box culverts should conform to the provisions for transitions hereinafter provided. Drainage structures having a minimum clear height of 8 feet and being of sufficient width to pass maintenance vehicles may result in minimizing the number of required channel access ramps. Unless otherwise specifically authorized by the City Engineer, all crossing structures must have at least 6.0 feet of clear height.

g. Subdrainage

Concrete lined channels to be constructed in areas where the ground water table is greater than two feet below the channel invert, weep holes or other subdrainage systems are not required.

Areas where the ground water table is within two feet or less of the channel bottom, there shall be provided, special subdrainage systems as necessary to relieve water pressures from behind the channel lining.

Miscellaneous Hydraulic Calculations

1. Hydraulic Jump

a. Location

If the water surface from a downstream control is computed until critical depth is reached, and similarly the water surface from an upstream control is computed until critical depth is reached, a hydraulic jump will occur between these controls and the top of the jump will be located at the point where pressure plus momentum, calculated for upper and lower stages, are equal.

b. Length

The length of a jump is defined as the distance between the point where roller turbulence begins and water becomes white and foamy due to air entrainment, and the point downstream where no return flow is observable.

(1) For rectangular channels, the length of jump (L) for the range of Froude Numbers between two and twenty, based on flow depth, is given by the following equation:

$$L = 6.9\ (D_2 - D_1)$$

where D_1 and D_2 are the sequent depths.

(2) For trapezoidal channels, the length of jump (L) is given by the following equation:

$$L = 5D_2\left(1+4\sqrt{\frac{t_2-t_1}{t_1}}\right)$$

$L=5D_2(1+4(t_2-t_1/t_1)^{0.5})$

Where:

t_1 = width of water before jump

t_2 = width of water after jump

Side Slope	$L/(D_2-D_1)$
2:1	44.2
1:1	33.5
1/2:1	22.9
Vertical	6.9

2. Trash Rack Head Loss

The head loss through a trash rack is commonly determined from the following equation:

$h_{TR} = K_{TR}\ (V_n/2g)$

$K_{TR} = 1.45 - 0.45\ (A_n/A_g) - (A_n/A_g)^2$

Where:

K_{TR} = Trash rack coefficient

A_n = Net area through bars, in ft.^{2}

A_g = Gross area of trash rack and supports (water area without trash rack in place), in ft.^{2}

V_n = Average velocity through the rack openings (A/A_n), f.p.s.

For maximum head loss, assume that the rack is clogged, thereby reducing the value of A_n by 50%.

3. Side Channel Weirs:

The Los Angeles District Corps of Engineers, as mentioned earlier in this section, has developed a side channel spillway inlet. The City or AMAFCA may require this type of structure for drains outletting into their facilities. The Corps' procedure for designing a side channel spillway is as follows:

a. Set the top of that part of the main channel wall at the location of the proposed spillway about 6 inches above the computed water surface level in the main channel.

b. Determine the length of spillway (L) required to discharge the design inflow of the side inlet by the following equation, in which the maximum value of H is not greater than one and one-half feet.

$$L = \frac{Q}{CH^{3/2}}$$

where:

Q = discharge of side inlet, in c.f.s.

C = weir coefficient

H = depth of water over the crest of the side inlet in feet

c. Determine the depth of flow in the approach side channel at the upstream end of the spillway.

d. Set the side channel invert elevation at the upstream end of the spillway at an elevation below the spillway crest a distance equal to the water depth as determined in c., above, minus the assumed head on the spillway.

e. Set the side channel invert slope equal to the spillway and the main channel water-surface slopes.

f. By trial, determine the width of the side channel required to maintain a constant depth of flow at several points downstream from the upstream end of the spillway. The discharge at each of these points is assumed to be the difference between the initial discharge less the amount spilled over that part of the spillway as computed by $CLH^{3/2}$, in which C is 3.087 and H is equal to the critical depth over the crest (neglecting the velocity of approach).

g. Plot the widths thus determined for the side channel on the channel plan and approximate a straight or curved line through them to locate the point of intersection of this line and the main channel wall.

h. If the length between the assumed point at the upstream end of the spillway and this intersection point is equal to the length determined in b., above, the angle at the intersection indicates the required convergence for the side channel.

i. From the final layout determine the width and recompute the water surface in the side channel for the final design. The discharge over each portion of the spillway is calculated by using the average head between the two sections considered.

Channel Treatment Selection Guidelines

A. General

The selection of a treatment type or of a combination of treatment types for a channel within the Albuquerque area should be based on a rational assessment of the needs of the community as they relate to:

B. Flood Control

The magnitude of the flood control requirements and the consequences of a system failure should be considered foremost in the treatment selection process.

C. Drainage

The existing and future land uses, the specific on- and off-site drainage treatments, and watershed topography should each be evaluated in terms of their impacts on the channel system. The unmitigated hydrologic effects of urbanization generally include higher peak runoff rates from small frequent storms, more frequent runoff events, cleaner runoff (with respect to sediment), and increased annual runoff volumes.

D. Maintenance

The selection of a channel treatment type should include analyses of both short and long term maintenance. While maintenance efforts will vary between treatment types, all facilities should be able to function through one runoff event with no maintenance, through one flood season with very little maintenance and from season to season with regular, but minimal maintenance requirements.

E. Rights-of-Way and Easements

The cost of land and the availability of rights-of-way or easements should be considered in the channel treatment selection process. Rights-of-way and easements should be appropriately located, aligned and sized for the particular treatment type. Some treatment types may require significant construction easements, but much smaller permanent rights-of-way or easements. The likelihood of replacement or reconstruction should be considered when channel treatment selection is balanced against the configuration of permanent rights-of-way and easements.

F. Safety and Fence Requirements

The selection of a channel treatment type should be based on any special safety considerations dictated by adjacent or nearby land uses. Whenever a required channel treatment is not compatible with adjacent land uses, adequate safety hazard mitigation measures should be incorporated into the design and construction of the facilities. Channels with vertical walls of 30 inches or greater will require a barrier or fence. Minimum fence or barrier height shall be 42 inches.

G. Upstream and Downstream Channel Treatments

The treatment selection process for each channel reach should include an analysis of the impacts of existing and planned upstream and downstream treatment types on a proposed treatment type and in turn the effects of the proposed treatment on existing and planned upstream and downstream treatments.

H. Initial Cost and Life Expectancy

The initial construction costs of various channel treatment types is and will always be one of the most heavily weighted factors in the selection process. However, when viewed on a larger scale, maintenance and replacement costs can be more important to the total costs of providing adequate levels of protection over time, and therefore must be considered in the planning, design and construction of channel treatment measures.

I. Joint Use Possibilities

The opportunities for including other uses such as transportation and utility corridors, open space or recreation in the design should be considered when selecting a treatment type and when establishing rights-of-way and easements. The inclusion of any other uses must be self-supporting financially and in no way impair or delay the implementation of the drainage and flood control function of the facilities.

J. Sediment Transport and Channel Stability

Moving water has the ability to transport sediment. The amount of sediment per unit of water that can be transported is related to flow depth, velocity, temperature, vertical and horizontal channel alignment, the amount of sediment available, the size and density of the sediment available and many other minor but sometimes important parameters. A channel's stability can be defined in terms of its ability to function properly during flood event without serious aggradation and/or degradation and that its continued operation can be relied upon without extraordinary maintenance and repairs. While channel stability problems are largely associated with earth and flexibly lined channels, concrete lined, supercritical channels are not immune. Any time a downstream channel reach has a lower sediment capacity than some upstream reach, there is a potential for sediment accumulation. The following worksheets can be used to make qualitative determinations with regard to channel stability.

Detailed qualitative analyses must be performed for any design requiring construction in a major arroyo. Methods found in items C.7 and C.8 in the Bibliography at the end of Section 22.3 shall be used in sediment transport analyses.

K. Channel Stability

A stable earth-lined channel is defined for the purposes of design as one in which neither degradation or aggradation is occurring at such a rate that it causes a continuous and serious maintenance problem. Channel degradation can cause extensive damage to bridges and other crossing structures due to the undermining of their foundations. Channel aggradation on the other hand results in reduced channel and crossing structure capacities and, therefore, in increased frequency of flooding.

Channel Stability Changes

An Increase or Decrease in:	Will Have the Following Effect in the Channel	
	Increase	Decrease
Flow Rate	Degradation	Aggradation
Flow Velocity	Degradation	Aggradation

Flow Frequency.	Degradation	Aggradation
Flow Duration	Degradation	Aggradation
Flow Depth.	Degradation	Aggradation
Sediment Reaching the Channel	Aggradation	Degradation
Sediment Particle Size.	Aggradation	Degradation
Streambed Material Size	Aggradation	Degradation
Channel Vegetation.	Aggradation	Degradation

L. Channel Construction Details

1. **Earthwork**

The following shall be compacted to at least 90% of maximum density as determined by ASTM D-1557 (modified Proctor):

(1) The 12 inches of subgrade immediately beneath concrete lining (both channel bottom and side slopes).

(2) Top 12 inches of maintenance road. (either as subgrade or finished roadway if unsurfaced).

(3) Top 12 inches of earth surface within 10 feet of concrete channel lip. It is particularly important to compact earth immediately adjacent to concrete lip. This area is sometimes overlooked when forms are removed.

(4) All fill material.

2. **Concrete**

(1) Materials

(a) Cement type: ILA or I-IILA

(b) Minimum cement content: 5.5 sacks/c.y.

(c) Maximum water-cement ratio: 0.53 (6 gals. per sack)

(d) Maximum aggregate size: 1 ½ inches

(e) Air content range: 4-7%

(f) Maximum slump: 3 inches

(g) Minimum compressive strength (f_c): 3000 psi @ 28 days

(h) Class F Flyash meeting the requirements of ASTM C618 shall be proportioned in the mix at a 1:4 ratio of flyash to cement weight.

(i) Steel reinforcement shall be grade 60 deformed bars. Wire mesh shall not be used.

3. Lining Section

(a) Bottom width - 10 feet minimum

(b) Side Slopes - 1 vertical to 2 horizontal maximum slope

(c) Concrete lining thickness

All concrete lining shall have a minimum thickness of 6 inches.

The lining shall be thickened to 7 inches on the channel bottom and lower 18 inches of the side slope. When design velocity exceeds 30 feet per second, the bottom section shall be thickened to 8 inches.

4. Concrete Finish

The surface of the concrete lining shall be provided with a wood float finish. Precautions shall be taken to guard against excessive working or wetting of finish.

5. Concrete Curing

All concrete shall be cured by the application of liquid membrane-forming curing compound (white pigmented) immediately upon completion of the concrete finish.

6. Steps

Ladder-type steps shall be installed at locations suitable for rescue operations along the channel but not farther than 700 ft. apart on both sides of the channel. Bottom rung shall be placed approximately 12 inches vertically above channel invert.

7. Joints

(a) Insofar as feasible, channels shall be continuously reinforced without transverse joints. However, expansion joints may be installed where new concrete lining is connected to a rigid structure or to existing concrete lining which is not continuously reinforced.

(b) The preferred design avoids longitudinal joints. However, if included, longitudinal joints should be on side slope at least one foot vertically above channel invert.

(c) All joints shall be designed to prevent differential displacement and shall be watertight.

(d) Construction joints are normally appropriate at the end of a day's run, where lining thickness changes, and any time concrete placement stops for more than 45 minutes.

8. Reinforcing Steel for Continuously Reinforced Channels

(a) Ratio of longitudinal steel area to concrete area

$$A_{s\ \text{long}} \;/\; A_{c\ \text{long.}} \geq .005$$

(b) Ratio of transverse steel area to concrete area

$$A_{s\ \text{transv.}} \;/\; A_{c\ \text{transv.}} \geq .0025$$

Note: *In (a) and (b) above A_s = crossectional area of steel in the direction indicated; Ac = crossectional area of concrete in the direction indicated. Longitudinal = long.; transverse = transv.*

(c) Steel Placement: Temperature and shrinkage steel shall be placed so as to be in the top of the middle third of the slab, but at least 3" from the bottom of the slab. Longitudinal steel shall be on tip of the transverse steel. (NOTE: Inspectors must insure this requirement is not violated by contractors during pouring operations.)

22.8 Street Hydraulics

l. A secondary use of the street network is the conveyance of stormwater runoff. This secondary use must always be subsidiary to the primary function of streets which is the safe conveyance of people and vehicles. The goals of street hydraulic design are therefore:

a. To provide an economical means of transporting stormwater runoff.

b. To ensure that the safety and convenience of the public are preserved.

c. To prevent stormwater runoff, once collected by the street system, from leaving the street right-of-way except at specially designated locations.

2. Street hydraulic design critical are as follows:

a. Manning's roughness coefficient is 0.017.

b. The calculated HGL for the 100-year design discharge may not exceed curb height and the calculated EGL shall be contained within the street right-of-way.

c. For a sump condition, the HGL for the 100-year storm may extend to the street right-of-way.

d. Flow depths in the event of the 10-year design discharge may not exceed 0.5 feet in any collector or arterial street. One lane free of flowing or standing water in each traffic direction must be preserved on arterial streets.

e. The product of depth times velocity shall not exceed 6.5 in any location in any street in the event of a 10-year design storm (with velocity calculated as the average velocity measured in feet per second and depth measured at the gutter flowline in feet.)

f. Gutter pan slope should be accommodated in the street cross-section.