Addendum

Revised Drainage Basin Fees Based on Impervious Area
For Unincorporated El Paso County Only

City of Colorado Springs & El Paso County
Drainage Criteria Manual

COORDINATED WITH
EL PASO COUNTY STAFF
AND
DRAINAGE CRITERIA MANUAL REVISIONS TASK FORCE

TECHNICAL WORK BY AYRES ASSCIATES AND SEC OLSSON ASSOCIATES

DRAINAGE BASIN FEE ADDENDUM
CHAPTER 3

This revised fee addendum is intended to supplement Chapter 3 in the Drainage Criteria Manual. It is only effective for use in El Paso County (not in the City of Colorado Springs). Many of the items outlined in Chapter 3 remain applicable to the basin fee calculation process. If a discrepancy exists between this addendum and the original Chapter 3, this addendum shall apply.

3.5a Impetus for Revisions to the Basin Fee

The implementation, maintenance, and improvement of an adequate drainage system in the County were not occurring because of several past problems with assessment and collection of the basin drainage fees. Drainage fees were unreasonably high in some areas, and several land developers had sought and performed "end runs" around the fee payment. Those challenges to the payment of drainage fees had been successful for the following reasons:

- The County's drainage basin fee system did not meet the legal test for proportionality. For stormwater, the proportionality test means that the fee for a development should be roughly proportional to the increase in stormwater runoff that the development generates. Therefore, the fee should not be based on the total acreage of a development (as was in the previous system) but on the number of impervious acres.
- The County's policy for the type of stormwater detention ponds required (regional and/or on-site) was not clear.
- A County policy for implementing regional detention ponds and other regional facilities had not been established.

In the County, a land owner can apply credits earned from one project towards another project within the same basin. However, credits earned in one basin may not be transferred to another basin.

In general, the City of Colorado Springs does not collect fees on replats unless required as a condition of annexation; however, the County does collect fees on replats as explained below.

3.6a History of the Fee Revision Process

El Paso County has levied a basin fee based on acres of development since 1983. Because of the proportionality and general equity issues raised above, the basin fee revision process began in 1998 that culminated in the issuance of a September 21, 1998 draft report entitled "Proposed Revisions - Drainage Basin Fee Program and Policy for New Development, El Paso County, Colorado" along with a subsequent November 17, 1998 Addendum to clarify on-site detention policy and correct minor typographical errors. A key finding of that report was that basin fees should be based on impervious acres rather than gross developed acres.

Following a review of the above draft, the development community believed that many of the revised basin fees were too high. As such, the developers hired the engineering consulting firm Ayres Associates to investigate the "Prudent Line" approach where applicable in lieu of structural channel improvements in an effort to reduce basin drainage infrastructure costs. The

Prudent Line concept allows for an erosion setback and grade control stabilization of natural channels in basins with low-density development. Using the findings of Ayres Associates, including the revised land costs for the Prudent Line approach, a Second Addendum was issued in July 1999, where basin fees were revised significantly downward in many of the basins and a basin fee cap of $15,000 per impervious acre was recommended. Various credits and reductions were also addressed and illustrated in examples in that addendum.

A Third Addendum was issued in September 1999 to clarify and resolve two objections made by developers following the issuance of the Second Addendum, and to resolve a few additional minor issues that arose as the Third Addendum was being finalized.

The information contained in the original September 1998 report and the three addendums have been used to prepare this revision to the basin fee program in the El Paso County Drainage Criteria Manual (DCM).

3.7a Calculation of the Basin Impervious Area

Impervious area in a basin is calculated for several different reasons. When a drainage basin planning study (DBPS) is completed the imperviousness is estimated to help determine peak runoff rates and runoff volumes under existing and future development conditions. The peak runoff rates and volumes are used to project floodplains and design conveyance and detention improvements. The costs of these improvements are, in turn, used to determine drainage basin fees for new development. Because the costs of improvements are dependent on the estimates of imperviousness in each basin, it is logical to base drainage basin fees on the amount of imperviousness in each development.

This new method is different that the previous method which used the same cost for each acre of development, regardless of the amount of impervious area planned for that acre. This method is still in use in the City of Colorado Springs.

The impervious area can be determined by direct measurements off the final development plan or by calculating the product of total area (both impervious and pervious area) and the percentage of area that is impervious. Table 3-1 shows some typical amounts of impervious area for different types of development. These values are generally consistent with Table 5-1 in the Colorado Springs/El Paso County Drainage Criteria Manual. Four additional single family residential values have been added to Table 3-1 that are not included in Table 5-1. Those values are for the 0.2-acre and the 6,000 square foot sizes for the smaller lots and the 2.5 and 5.0-acre sizes for the larger lots. The percent impervious values for these additions have either been directly computed or estimated from a regression of the existing values in Table 5-1 in the DCM.

Table 3-1
Typical Values of Percent Impervious

Type of Development	Percent Impervious
Commercial	95%
Industrial	85%
Multi-Family	65%
Single Family - 0.1377 acre lots (6,000 SF)	53%
Single-Family – 0.20 acre lots	43%
Single-Family – 0.25 acre lots	40%
Single-Family – 0.33 acre lots	30%
Single-Family – 0.5 acre lots	25%
Single-Family – 1.0 acre lots	20%
Single-Family – 2.5 acre lots	11%
Single-Family – 5 acre lots	7%

The total impervious area may also be determined from direct measurement made by the developer. A developer may wish to do this if the average numbers presented in Table 3-1 do not apply to a specific development. If the developer chooses to do this, all impervious areas within the development should be included. These areas include streets, parking lots, residential, commercial, tax exempt, parks, golf courses, and any other land use within the development. When different land uses are included in a development a composite percent impervious should be used.

3.8a Computation of the Basin Fee

The following example uses the typical impervious area numbers. In the computation of the basin fee, the developer or their representative shall obtain the appropriate basin fee from Exhibit 1 of the September 13, 1999 BOCC Resolution No. 99-383, or more current revision.

Example 1:

What is the fee for a 40-acre residential development in Dirty Woman Creek basin with 0.5-acre lots? The developer is not required to build any reimbursable stormwater facilities in this example and does not qualify for a low-density reduction or an on-site detention pond credit.

From Table 3-1, the percent impervious is 25%.

Calculate the impervious area for the site:

25% x 40 acres = 10 acres

Calculate the fee for the entire development:

$14,454 per impervious acre x 10 impervious acres = **$144,540**

Alternatively, the developer in each case could determine impervious area from the property plat, as illustrated in Example 2 below.

Example 2:
What is the fee for a 40-acre residential development in Dirty Woman Creek basin with 0.5-acre lots? The developer is not required to build any reimbursable stormwater facilities in this example and does not qualify for a low-density reduction or an on-site detention pond credit.

The developer has prepared his site plan using AutoCAD, and has instructed his designer to draw all streets, driveways, sidewalks, patios, and building footprints (i.e., all impervious areas) for the entire platted area as closed polylines. The designer can quickly use AutoCAD to compute the total area of those polylines, and determines that those impervious features comprise 22.8% of the platted area.

Thus the *measured* impervious area for the site is:

22.8% x 40 acres = 9.12 acres

Calculate the fee for the entire development:

$14,454 per impervious acre x 9.12 impervious acres = **$131,820**

3.9a Routine Fee Updates

Drainage basin fees are subject to an annual revision based on the current construction cost index. It is important that fees are revised to reflect actual construction costs, otherwise the fees will be inadequate to construct needed improvements to protect residents.

The current drainage and bridge fee schedule in effect shall be attached to the September 13, 1999 BOCC Resolution No. 99-383, and updated annually.

3.10a Credits and Reimbursements

3.10.1a Reductions Versus Reimbursements

Reductions in fees will be made for certain low-density type developments and prudent line land where applicable. Partial reimbursement of construction costs will be made to developers for construction of on-site detention ponds that meet County criteria. Full reimbursement of construction costs will be made to developers for construction of regional facilities in general accordance with the DBPS or as approved by the County prior to construction. Reimbursements for pond construction will only be made if sufficient basin funds are available.

3.10.2a Fee Reductions for Low Density Lots

A reduction in the drainage basin fee is proposed if a development consists of 2.5 or 5.0 acre lots.

A land developer may qualify for a 25 percent reduction in drainage basin fees if he is developing an area into 2.5 acre and/or 5.0 acre lots. The reduction is proposed because a significant portion of the stormwater from these large lots does not flow directly into the County stormwater system, but flows into the yards as sheet flow and infiltrates into the ground. The impervious area on a rural property does not create as much runoff as the same impervious area located in an area with smaller lots and curb and gutter paved roadways. Runoff from these smaller, more urban lots, flows more directly into the County stormwater system. However, the roads serving the larger lot rural areas do create additional stormwater that flows directly into the County system along with some increased flow from the residential lots. Therefor,e runoff from these areas shows an increased over the historic conditions. The proposed reductions are based on the 1986 version of the Natural Resources Conservation Services' Technical Release Number 55, which includes a procedure that accounts for "disconnected impervious area".

In a mixed-use development, only the 2.5 acre and/or 5.0 acre area will receive the reduction. Example 3 below illustrates that adjustment.

Example 3:
What is the fee for a 100-acre residential development with 60 acres of 2.5-acre lots and 40 acres of 0.5-acre lots? The development is in the Bennett Ranch basin.

Calculate the fee for the portion of the development with 2.5-acre lots:

Impervious area = 11% x 60 acres = 6.6 acres
The developer gets a 25% reduction for the 2.5-acre lots.
6.6 impervious acres x 75% x $7,613 per impervious acre = $37,684

Calculate the fee for the remaining 40 acres of 0.5-acre lots:

Impervious area = 25% x 40 acres = 10 acres
10 impervious acres x $7,613 per impervious acre = $76,130

Add the fees for the two areas to get the gross fee:

$37,684 + $76,130 = **$113,814**

3.10.3a Fee Reductions for Land Required to be Dedicated for the Prudent Line

Fee reductions are also available for the cost of land within dedicated Prudent Line easements (outside of the floodplain). Developers that dedicate Prudent Line easements according to a County accepted Prudent Line report can reduce their fees by the value of the easement. The amount of the reduction will be the same as the land cost that was used in the basin fee calculation, which is currently $5,000 per acre. This reduction rate shall be adjusted whenever the Parkland Dedication Fee is changed. If the reduction exceeds the gross fee, the fee shall be $0, and the remainder of the easement cost shall be applied as a credit, similar to those discussed below.

Example 4 below is the same as the previous Example 3, with the addition of Prudent Line considerations in the computation of the basin fee.

Example 4:
What is the fee for a 100-acre residential development with 60 acres of 2.5-acre lots and 40 acres of 0.5-acre lots? The development is in the Bennett Ranch basin, and 8 acres of the 2.5-acre lots are within the Prudent Line setback area. The developer is not required to construct grade control structures.

Calculate the fee for the portion of the development with 2.5-acre lots:

Impervious area = 11% x 60 acres = 6.6 acres

The developer gets a 25% reduction for the 2.5-acre lots.

6.6 impervious acres x 75% x $7,613 per impervious acre = $37,684

Calculate the fee for the remaining 40 acres of 0.5-acre lots:

Impervious area = 25% x 40 acres = 10 acres

10 impervious acres x $7,613 per impervious acre = $76,130

Add the fees for the two areas to get the gross fee:

$37,684 + $76,130 = $113,814

The fee is reduced by the cost of the land for the Prudent Line setback:

$113,814 – (8 acres x $5,000 per acre) = **$73,814**

3.10.4a Reimbursement of Construction Costs for On-Site Ponds

A land developer may qualify for a reimbursement of a portion of the construction costs if he builds on-site detention meeting specific criteria. Recognizing that on-site ponds provide some benefits to the regional system of a basin, 50% of the cost of a small on-site pond may be reimbursed to the developer if the following criteria are met:

1. Allowed only where regional system is not yet in place.
2. The pond is less than 15 acre-feet in volume from the lowest outlet structure to the crest of the emergency spillway.
3. The on-site pond is <u>not</u> part of the regional plan (for approved ponds that are part of the regional plan, developers are given 100% credit).
4. The outlet of the pond must be designed to release at historical levels for all precipitation events from the 2-year storm to the 100-year storm. A smaller outlet may be required by the County if adequate downstream channel improvements are not in place to protect residents from the 2-year storm flows.
5. County approves design and construction.
6. Landowners assume responsibility for maintenance.

The purpose of this reduction is to allow developers to integrate detention into their developments when sites lend themselves to multiple uses such as parks, open space, athletic fields, golf courses or others. Another reason for implementing regional detention on-site is to provide adequate protection to downstream properties that may be threatened from increased flows from the development when regional improvements are not to be implemented within an acceptable time frame. The reason for the 2-year event criteria (or smaller if adequate channels are not in place for 2 year flows) is because of the significant number of smaller events that will pass through a 5-year outlet. Those more frequent events are responsible for much of the erosion and other problems downstream of new developments and the County is left to repair erosion or deal with other problems.

If the above requirements are not met, the on-site detention will not qualify the land developer for a reimbursement of costs. If the developer chooses not to construct an on-site regional pond, he may still have to construct a conventional on-site pond to prevent downstream impacts from his development. It is important to note that reductions for meeting certain on-site detention criteria and for development that consists of 2.5 or 5.0 acre lots (discussed above) cannot both be applied to the same development.

Example 5 below illustrates the reduction in the basin fee for construction of a qualified on-site detention pond.

Example 5:
What is the fee for a 10-acre commercial site with a small on-site detention pond (2 acre-foot pond with estimated construction cost of $40,000), which meets the County criteria for a pond reimbursement? The fee will be reduced by 50% of the estimated cost of the pond construction, i.e., $20,000. The site is in the Big Johnson Reservoir/Crews Gulch basin.

Calculate the gross fee:

95% x 10 acres x $15,000 per impervious acre = $142,500

Calculate the fee after the reduction for the pond:

$142,500 - $20,000 = **$122,500**

3.10.5a Reimbursement of Land and Construction Costs of Other Regional Facilities

The system of credits for the costs of construction of regional structures has not changed from the current system. The current system gives credits to developers for building projects that are listed in the DBPSs. A developer is reimbursed for these credits after the construction is complete and accepted by the County, and when there are sufficient basin funds. Alternatively, credits may be used to reduce the fees for subsequent developments in the same basin.

In addition to regional structures in the DBPSs, credits are given for the following structures:

- Total reimbursement of the construction costs of large on-site ponds that are accepted into the regional system by the County.
- Reimbursement of 50% of the cost of small on-site ponds (less than 15 acre-feet) that meet County criteria. This credit will not exceed the amount of the fee. If the construction cost is more than twice the gross fee, the credit will be equal to the fee.

3.11a Appeals Process

The procedures outlined for basin fee computation are generally straightforward. However, some developments may result in a more complex computation of the basin fee, and the result may be a disagreement between the developer and the County in the fee computed. The developer and County should attempt to resolve the disputed fee. In the event the attempted resolution is unsuccessful, the developer may elect to appeal the disputed fee amount to the

Subdivision Storm Drainage Board. The developer will need to prepare a written appeal detailing the disputed basin fee amount and provide calculations or other evidence supporting his fee calculation. That written appeal is due by 4:00 P.M. on the third Thursday of the month prior to the next month's Drainage Board meeting. The Drainage Board will review the written appeal at their regularly scheduled meeting and render a final decision on the basin fee that will be due.

3.12a New/Revised Drainage Basin Planning Studies

Basin fees may be updated between annual routine fee updates if new or revised DBPSs are prepared for a basin and accepted by the County. These updated fees will be reflected in Exhibit 1 of the September 13, 1999 BOCC Resolution No. 99-383.

3.13a Vacations, Replats, Drainage Districts, and Irrigation Companies

The overriding guideline regarding replats and vacations will be whether an increase in impervious land cover would result. If impervious land cover over the revised plat is not increased, then no reconsideration of the basin fee will be made, whether or not a fee has been previously paid. If the impervious land cover of the affected parcel(s) increases, then reconsideration of the basin fee will be made, whether or not a basin fee has been previously paid.

A plat vacation occurs when two or more contiguous lots are combined into one lot. In this situation, the percent impervious acreage would generally not increase unless the development type changed, for example from low density 2.5-acre lots at 11 percent impervious to multi-family units at 65 percent impervious. In that case, a basin drainage fee would be required whether or not a fee had been previously paid. If a basin fee had been previously paid, then the fee due for the vacated and replatted land would be reduced by the amount of the fee (with no adjustment for inflation) paid previously. However, no refund of any or all of a previously paid fee would be made if the new basin fee is less than the fee paid previously.

A replat of a lot or parcel occurs when it is divided into two or more contiguous lots. In this situation, the percent impervious would generally increase unless the development type changed from high density such as multi-family units at 65 percent impervious to low density such as 2.5-acre lots at 11 percent impervious. Regardless of whether the replatted land density increased, decreased, or did not change, a basin fee would still be required for a replat if no fee had been previously paid. If a basin fee had previously been paid for the parcel before the replat, the new fee would be reduced by the amount of the fee (with no adjustment made for inflation) paid previously. However, no refund of any or all of a previously paid fee would be made if the new basin fee is less than the fee paid previously.

If a developer or landowner enters into any agreement or special arrangement with a drainage district or irrigation company, that individual or company is not relieved of their obligation to pay the County basin and bridge fee. Any drainage improvement made by the land developer has to be identified as a proposed improvement in the Drainage Basin Planning Study (DBPS) for that specific basin in order to be considered for reimbursement of construction cost. If no DBPS exists for the basin or if the land developer proposes a substantial departure from the drainage improvement(s) shown in the existing DBPS, the developer must either fund the preparation a DBPS for the basin (if none exists) or revise the existing DBPS to the satisfaction of the County in order to receive consideration for reimbursement of costs of construction for drainage facilities.

Prudent Line Addendum

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1. GENERAL STATEMENT

Urban development adjacent to natural stream channels poses complex problems for planning and regulatory agencies and developers. Due to the dynamic nature of most natural stream channels, it is imperative that appropriate steps be taken to protect adjacent structures and facilities from damage due to flooding and erosion. Lining channels with nonerosive or erosion-resistant material is a common protection method; however, the cost associated with this "hard lining," in terms of construction and maintenance costs, as well as degradation of the natural environment, may be unacceptable. Additionally, channels left in a natural or naturalistic condition can provide improved aesthetic value, better water quality conditions and opportunities for multi-use development, including bike trails, parks and greenways.

However, any natural channel, from a small swale to a major river, exists in a dynamic environment and can move both laterally and vertically with time. Therefore, when a channel is left in its natural condition it is necessary to limit how close development can occur next to the channel to minimize potential property damage as a result of future channel migration and flooding. This requires definition of a setback, or erosion risk boundary, within which development is not allowed. In some metropolitan areas, this setback or erosion risk boundary has been referred to as the "prudent line," since without major channel stabilization measures it would not be prudent for development to occur within this boundary.

The definition of a prudent line must recognize both the short-term impacts of flooding and erosion and the cumulative impacts of erosion over the long term. The physical processes involved with channel migration and the analysis of those processes are inherently complex. The procedure outlined in this addendum is a gross simplification of this process in an attempt to establish a procedure that is easily applied, yet provides reasonable definition of a "prudent line." The procedure was developed specifically for application to rural basins in El Paso County, Colorado, where the land use density is low and the application of the prudent line concept is justified given both engineering and economic considerations. Definition of a prudent line in other areas, particularly basins with higher density, should be based on a more comprehensive and detailed analysis than outlined in this addendum.

Engineers and designers applying the procedures outlined in this addendum should have training or experience in water resource engineering, including hydrology, hydraulic and sediment transport concepts. It is generally recognized that the calculation of a floodplain boundary requires a certain amount of specialized water resource engineering knowledge. This is equally true, if not more so, for the analysis and calculation of a prudent line boundary. Therefore, the application of this procedure should be completed under the responsible charge of an adequately qualified and licensed Professional Engineer

2. PRUDENT LINE APPLICABILITY

Table 1 below presents criteria defining applicability of the prudent line approach. The prudent line approach is the recommended alternative for all rural El Paso County basins unless the basin conditions preclude its use. The county Engineering Division under the Department of Transportation shall make the final determination of whether the prudent line is applicable within a rural basin. The user should follow the decision tree presented in **Figure 1** to determine the applicability of the prudent line for development within the basin.

Table 1. El Paso County Prudent Line Applicability Criteria.
DCM prudent line approach is applicable and recommended for: Open channel segments located downstream from land having less than or equal to a cumulative 15 percent impervious surface cover under future conditions <u>and</u> the main channel can adequately convey future conditions 10-year event flows.
DCM prudent line approach may apply to: Open channel segments located downstream from land having between a cumulative 15 and 20 percent impervious surface cover under future conditions <u>and</u> the main channel can adequately convey future conditions 10-year flows. These reaches require justification for recommending the prudent line approach.
DCM prudent line approach is not recommended for: Open channel segments located downstream from land having greater than a cumulative 20 percent impervious surface cover under future conditions <u>or</u> main channel lacks adequate conveyance capacity for the future conditions 10-year flows. However, the prudent line may still be considered if a detailed analysis of the prudent line is conducted using more advanced analytical techniques. The detailed approach must be completed by a firm experienced in conducting an advanced prudent line analysis. In addition, channels with in-line detention ponds and channels with transitions to/from improved channels and bridges may not be appropriate for prudent line treatment (see “Transitions” below).

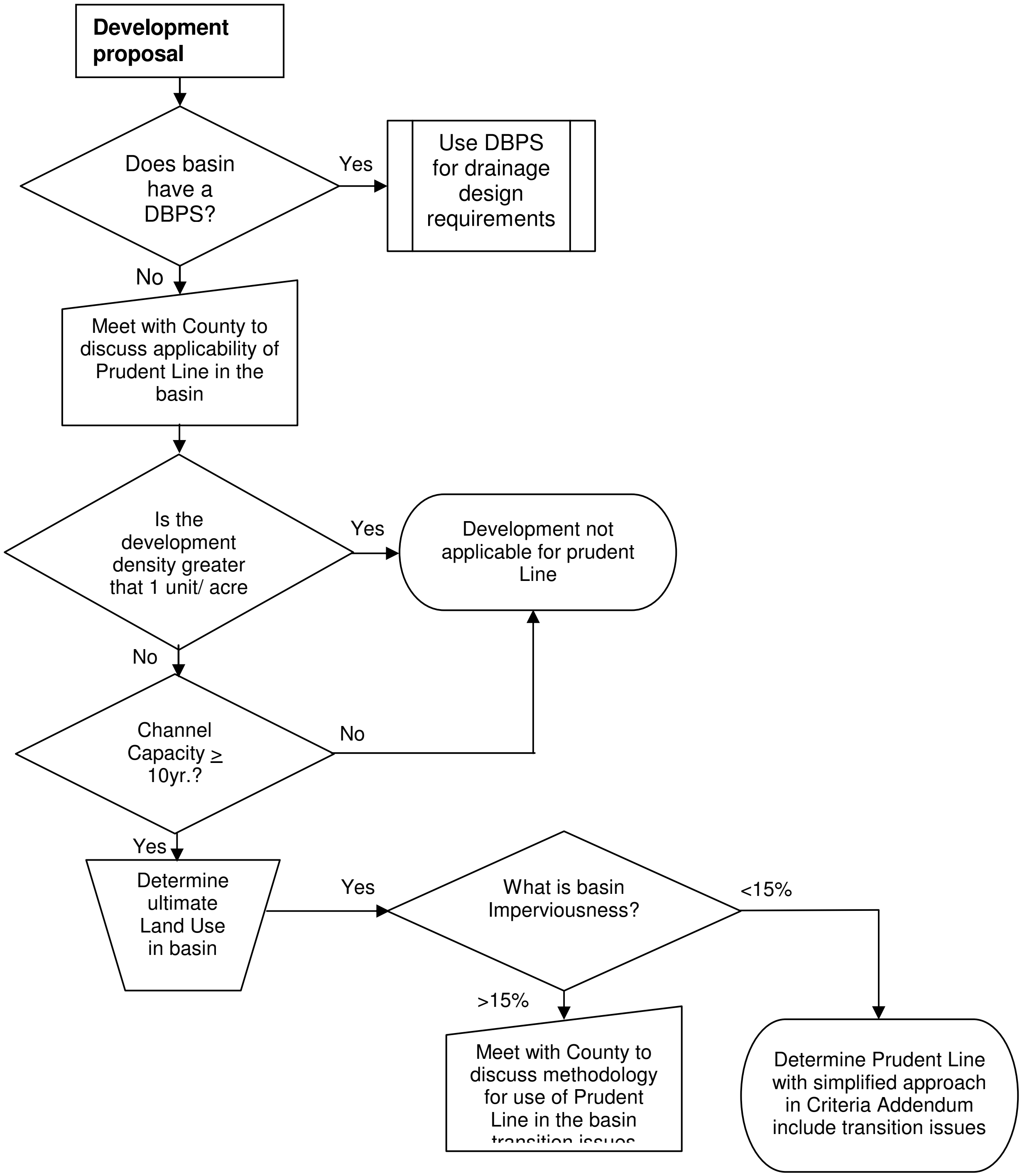


Figure 1. Decision tree to determine applicability of prudent line.

There may be other factors that would prevent the use of the prudent line. These generally relate to the ability of the stream to transport sediment during minor to major storm events. For example, stream improvements upstream of the proposed prudent line reach, an excessive number of stream crossings (more than one about every mile should cause concern), improperly designed transitions at road crossings, or on-line detention ponds either upstream of or within the prudent line reach are all factors that should be evaluated, and the impacts of assessed, when prudent line is considered for a given reach in a rural El Paso County basin.

2.1 Transition Issues

Transition issues on the prudent line reaches require special consideration because of the differential velocities that often arise, thus causing sediment deposition and/or excessive erosion. Transitions usually involve one of the following two cases:

Case1: the transition between an improved channel reach and a prudent line reach, or vice versa, and
Case 2: the transition that is necessary at road crossings on a prudent line reach.

For Case 1 where a proposed prudent line reach is downstream of an improved reach, and the prudent line natural channel is wider than the improved channel, the improved channel should be graded to transition to the prudent line reach using a 4:1 (longitudinal distance to lateral distance) flare ratio. The transition should be designed to ensure that velocities have been adequately reduced to a non-erosive level (generally 5 to 6 feet per second maximum) in the prudent line reach. For the reverse situation where a prudent line reach transitions to an improved channel section, a convergence ratio of 2:1 should be used. The transition hydraulics should be carefully evaluated to prevent the converging flow from getting sufficiently deep to result in overtopping of the protective lining (e.g., riprap) of the improved channel section, thus resulting in erosion behind the lining. In addition, Froude numbers should remain less than 0.8 to prevent any unstable flow characteristics or depths near critical depths to occur. Because of the additional turbulence caused by expanding or converging transitions, riprap may be required to provide additional erosion protection or to provide additional channel roughness for reducing velocities.

For Case 2, the optimum situation at road crossings would be to provide a crossing sufficiently wide so that upstream velocities do not decrease to a level where sediment will drop out (i.e., the crossing would essentially span the entire floodplain). Obviously that is not always practical, but wider crossings over prudent line reaches will nonetheless be required. One of the key benefits of the prudent line approach on rural basins is that the additional costs associated with oversized crossings and prudent line setback land acquisition will be more than offset by the cost savings in constructing channel stabilization measures rather than full scale improved channel. As such, the following guidelines should be followed when designing roadway crossings on prudent line reaches:

1. the culvert should be sized to convey the 10-year future condition discharge with no more than a 20% change to the channel depths and velocities that would occur at a location immediately upstream and downstream of the crossing, assuming the crossing did not exist.
2. riprap should be designed to protect the channel upstream and downstream of the crossing for the larger recurrence interval events such as the 50- and 100-year, as those floods would result in higher velocities.

Again, it is important to stress the point that an excessive number of road crossings (more than about one per mile) would jeopardize the applicability of the prudent line, even if other criteria are met.

2.2 Defining the Prudent Line

The concepts of hydrologic uncertainty and risk are useful in establishing the location of the prudent line within which development should not occur due to erosion and flooding considerations. It is seldom practical to provide absolute protection against the maximum probable flood. It is, therefore, necessary to accept some degree of risk. The problem, then, is one of relating the prudent line to an acceptable degree of risk. In the hydrologic sense, risk is normally associated with the return period (or recurrence interval) of an event that may result in erosion or flooding within a given channel or watercourse.

The National Flood Insurance Program (NFIP) establishes the 100-year flood as the minimum level of risk that is acceptable when considering potential impacts due to flooding. Therefore, to evaluate the short-term impacts of flooding, as well as erosion, the 100-year flood is a reasonable criteria to include as part of the prudent line methodology.

While damages due to flooding are generally associated with a single, short-term event, the impacts of erosion can also be cumulative over the long term. Consequently, one must assess the erosion potential not only of a single event, such as a 100-year flood, but also the cumulative impact of a series of smaller flows over a multi-year period. The problem is then defining how many years constitute "long-term."

The use of the 100-year event as the level of acceptable risk provides insight for a reasonable definition of long-term conditions. Based on hydrologic risk concepts, there is approximately a 74 percent chance that the 100-year event will not occur in a 30-year period. Conversely, this implies a risk of about 26 percent that the event will occur within a 30-year period. Considering the risk of a single large flood (e.g., the 100-year event) in a 30-year period, as well as the inherent limitations related to long-term prediction of channel migration, an acceptable definition of long-term for analysis of cumulative erosion is 30 years.

The criteria for defining the prudent line is then defined as the enveloping curve considering the 100-year floodplain boundary, the erosion during a 100-year event, or the long term erosion over a 30-year period.

2.3 The Maintenance Line

The prudent line concept allows the stream to function naturally within the constraints of protecting existing infrastructure. Future development is provided for by maintaining a safe distance horizontally and vertically from the creek. However, due to the dynamic nature of stream channels, and the limitations of any analysis that attempts to predict future channel conditions, it is possible that the prudent line may be encroached on in the future. If this happens limited structural improvements may be necessary, and while the channel may no longer be completely "natural," it is still "naturalistic," with selective erosion barriers, or countermeasures, applied.

To plan for this potential occurrence, any prudent line application should incorporate a "maintenance line," located somewhere inside the prudent line. Should the channel begin to encroach on the maintenance line, some remedial measures should be considered so that the prudent line is not jeopardized. These remedial measures could include rock riprap, regrading and revegetating, spur dikes, or other available channel stability countermeasures.

Therefore, while maintenance issues and the need for structural improvements are greatly reduced with a prudent line approach, they may not necessarily be eliminated. The concept of a prudent line requires, by its very nature, less maintenance; however, it is important to recognize the potential need for future erosion protection. Finally, while the basic concept of a prudent line is to establish a buffer zone that permits the channel to exist in its natural state, it is acknowledged that existing encroachments and utilities may require protection. Channel stabilization measures may be necessary to protect existing infrastructure along a channel that has a designated prudent line. However, these channel stabilization measures must be carefully designed to avoid adversely impacting the prudent line in an adjacent reach.

It is also important to note that the County will be responsible for performing channel rehabilitation measures on the prudent line channel resulting from significant hydrologic events or from long-term erosion. However, the property owner will be responsible for providing protection to his or her structures.

2.4 Maintenance Access

Providing maintenance access to the prudent line channel is very important. Generally, the prudent line channel will intersect the County road grid located along section lines at approximately one-mile intervals. Access to the channel by machinery and personnel can be provided at those locations. There may be channel maintenance operations that need to be performed in between the County road locations, and for that reason, it is required that maintenance access be provided for both sides of the channel in accordance with **Table 2** below.

Table 2. Prudent Line Maintenance Criteria.		
Type of Development	Maintenance Access Requirements	Other Conditions
Lot sizes ≤ 2.5 acres along channel	Provide access to channel at a maximum one-quarter mile interval along lots with a minimum 15-foot-wide easement dedicated to El Paso County	• Property plats to show exact easement locations. • Routine maintenance (mowing, weed treatment, trash pickup) to be responsibility of landowner. • County to be responsible for restoration due to County-sponsored construction activity.
Lot sizes > 2.5 acres along channel	Provide access to channel through each lot via a minimum 15-foot-wide easement dedicated to El Paso County	• Each platted lot to contain a note that a 15-foot-wide easement has been provided to El Paso County. • The lot owner has discretion over the location of the access easement as long as it is passable by typical construction equipment. • Routine maintenance (mowing, weed treatment, trash pickup) to be responsibility of landowner. • County to be responsible for restoration due to County-sponsored construction activity.

3. CALCULATING THE PRUDENT LINE

3.1 Methodology

Two separate prudent line procedures were developed based on the two dominate channel types found in El Paso County (Ayres Associates, "Prudent Line for Rural Areas, El Paso County," Draft Report, June 2000). One procedure is for channels in sandy soils and another for those incised into more erosion-resistant material. The procedure for sandy soils is a simplified approach to the procedures that have been successfully used in the Albuquerque, New Mexico area, and the erosion-resistant procedures are based on the approach used in Cottonwood Creek, Colorado.

Both procedures are simplified methodologies that should be carefully applied using reasonable engineering judgement. The procedures were developed to address channels experiencing, or potentially experiencing, erosion-related stability issues. Depositional reaches can also experience channel instability; however, the prudent-line concept may not be the best solution in these situations (Section 3.7). These methods should not be applied to channels with Q100 greater than 10,000 cfs, or to channels with unusual or unique sediment transport conditions, including alluvial fans or channels below reservoirs or detention ponds.

3.2 Prudent Line for Sandy Soils

The prudent line for sandy soils is based on a simplified sediment continuity analysis to define a potential sediment deficit. The bed material sediment transport capacity for a range of floods can be calculated based on a triangular hydrograph approximation of return period flood hydrographs (100-, 50-, 25-, 10-, 5-, and 2-year), given a sediment transport relationship in the form of $Q_s=aQ^{b.}$ The sediment transport relationship was developed assuming sediment concentrations by weight ranging from 1,000 to 15,000 ppm.

Step 1. Calculate the sediment transport capacity for different return period events.

Apply Equation 3.1 to calculate the total bed-material sediment volume in transport (sediment transport capacity) for the 100-, 50-, 25-, 10-, 5-, and 2-year flood hydrographs:

$$VOL_i = 6\ Qp\ d \qquad (3.1)$$

where:

VOL_i	=	bed-material sediment volume (cf) for the i - return period flood
Qp	=	peak discharge (cfs) for the i - return period flood
d	=	hydrograph duration, (hr) , as approximated by triangular hydrograph

The El Paso County Drainage Criteria Manual requires hydrology to be generated for the 100- and 5-year events. In that case, it is acceptable to plot those peak discharges on log-probability paper to estimate the intermediate return period peak flows used in Equation 3.1.

Step 2. Calculate the potential sediment deficit in any given reach of the study area.

Erosion occurs when the sediment transport capacity of any given reach exceeds the quantity of sediment supplied to that reach. In the absence of better information, assume a sediment deficit equal to 25 percent of the transport capacity is possible at any location throughout the study reach due to changes in slope, roughness, channel geometry, etc. Therefore, the potential sediment deficit for the i-return period flood in any given reach is:

$$Y_i = 0.25 \times VOL_i \qquad (3.2)$$

This assumption is reasonable for a channel reach that is relatively similar to the next upstream reach. If significant sediment storage is occurring upstream, such as at a detention pond or constricted roadway crossing, the deficit could be substantially greater and a more complex analysis of the prudent line will be necessary.

Step 3. Calculate the average annual sediment deficit

After calculating the potential deficit for each return period event, the average annual deficit is calculated using a probability weighting approach:

$$Y_m = 0.015Y_{100} + 0.015Y_{50} + 0.04Y_{25} + 0.08Y_{10} + 0.2Y_5 + 0.4Y_2 \qquad (3.3)$$

where Y_i represents the calculated deficit (cf) for the i - return period flood.

Step 4. Convert the calculated sediment deficit to a long-term lateral migration distance

To estimate potential long-term lateral migration, the resulting average annual deficit volume must be converted into a horizontal distance. For purposes of this analysis, it is assumed that all the sediment will be eroded from the channel bank, thus representing lateral migration. No sediment is assumed to come from the channel bed. Since the computed sediment deficit represents sediment in transport, a bulking factor must be applied to calculate the sediment volume that could be eroded from the channel boundary. Given a sand porosity of 0.4, the bulking factor would be 1.67 (i.e., 1/(1 - 0.4).

It is reasonable to assume that this long term lateral migration will occur primarily as a relatively uniform bankline retreat somewhere along the study reach. Assuming that this will occur along a 500 ft reach, the annual lateral retreat can be calculated given cross section data in the reach. This can be based on a typical cross section describing the channel and overbank geometry.

Using a 30-year period as the duration for long term erosion, the average annual migration value times 30 defines the cumulative long term erosion potential. Since the exact location of this retreat is not known, this offset should be applied to both sides of the channel along the given reach.

In summary, the calculations required in step 4 are to:

1. Multiply the calculated average annual deficit (Equation 3.3) by 1.67 (the bulking factor).

2. Estimate the potential lateral migration over a 500 ft reach based on a typical channel cross section (see **Figure 2** for some typical examples).

3. Multiply the calculated lateral migration by 30 and apply the computed offset to both sides of the channel, measured from the top-of-bank for the low flow channel. If a low flow channel is not apparent, measure from the location of the 10-year water surface.

Depending on reach length, channel geometry variability and changes in runoff along the reach as drainage area increases, this calculation can be based on a single reach, or multiple subreaches. In the case of multiple reaches, the computed distance should be applied from one calculation point upstream to the next, not in the downstream direction.

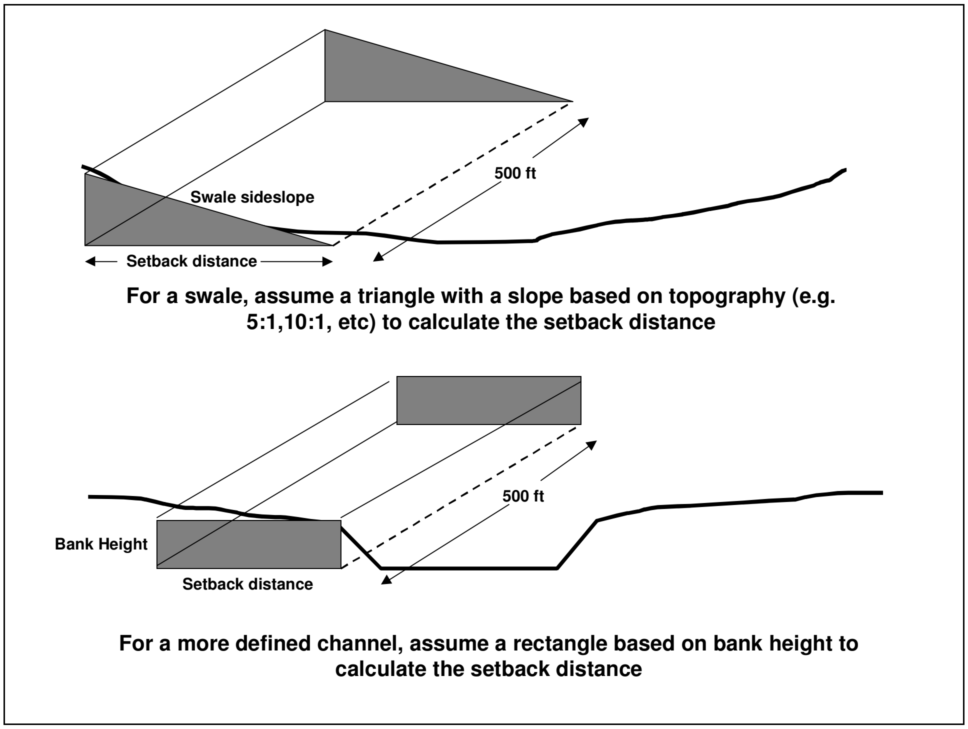


Figure 2. Examples of setback calculation for long-term erosion.

Step 5.   Calculate the short-term lateral migration distance

The short-term erosion potential must also be considered. This is based on the potential lateral migration during a single 100-year flood, based on the sediment deficit calculated above for the 100-year flood. However, instead of distributing this erosion in a linear fashion, as suggested for the cumulative long-term analysis, it is more reasonable to assume that such erosion in a single large event might occur as a scalloping of the bankline. Assuming a right triangle geometry with the length of one leg along the channel bankline equal to 150 ft, the length of the opposite leg (representing the scallop distance into the bankline) can be calculated given typical channel and overbank geometry. The location of this scallop is also unknown, and so the resulting offset distance should be applied to both sides of the channel along the given reach.

In summary, the calculations required in step 5 are to:

1. Multiply the calculated 100-year flood erosion deficit by 1.67.

2. Estimate the potential lateral migration assuming a right triangle with a 150 ft leg eroding into a bank described by the typical channel cross section (see **Figure 3** for some typical examples).

3. Apply the computed offset to both sides of the channel, measured from the top-of-bank for the low flow channel. If a low flow channel is not apparent, measure from the location of the 10-year water surface.

Depending on channel geometry variability, this calculation can also be based on a single reach, or multiple subreaches. In the case of multiple reaches, the computed distance should be applied from one calculation point upstream to the next, not in the downstream direction.

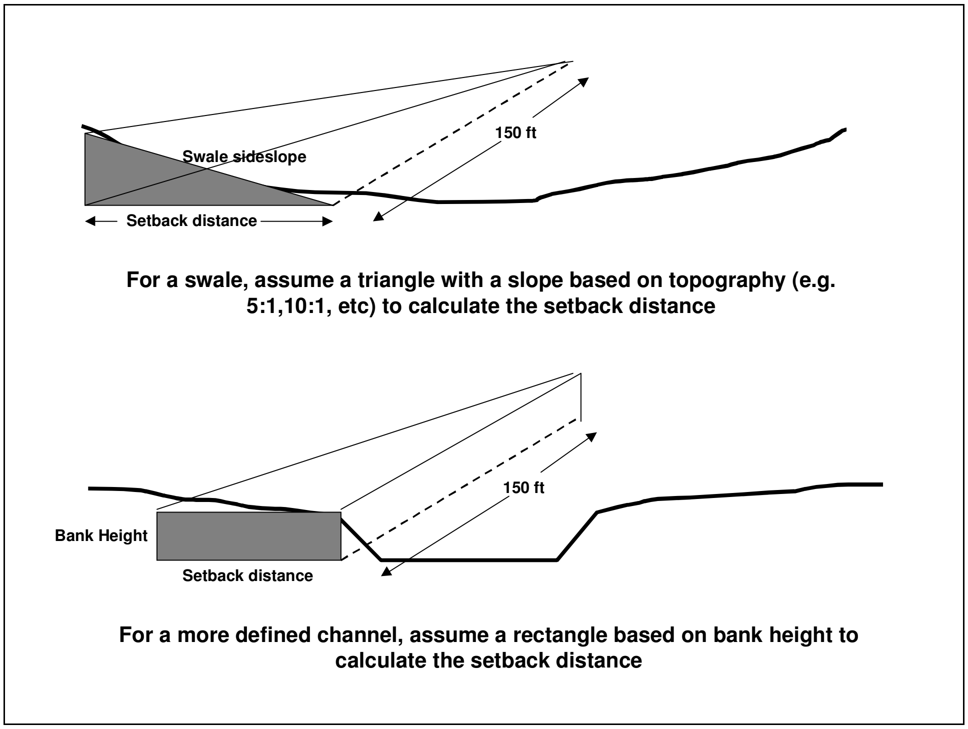


Figure 3. Example of setback calculation for short-term erosion.

Step 6. Minimum prudent line

The minimum prudent line offset recommended is 50 ft from the top-of-bank for the low flow channel. If a low flow channel is not apparent, measure from the location of the 10-year water surface.

Step 7. Tabulate and/or plot the prudent line

The prudent line for sand channels is based on an enveloping curve considering the greater of (1) the 100-year floodplain, (2) the calculated setback based long term (30 year) erosion, (3) the calculated setback based short term (100-year flood) erosion, or (4) the setback based on the low flow channel top-of-bank (or the 10-year water surface when a low flow channel is not apparent) plus 50 feet.

3.3 Prudent Line Methodology for Erosion-Resistant Material

Figure 4 presents the schematic and formula to use in defining the prudent line setback location for channels in erosion resistant material. The top of bank can be defined by reviewing topographic mapping. The bank line is represented by very closely spaced contours along the valley margins. This steep slope is different from the valley wall slope, in that the valley wall slope contours are not as closely spaced. The valley wall crest is represented by a significant change in the closeness in contour spacing.

Step 1. Calculate the maximum bank height

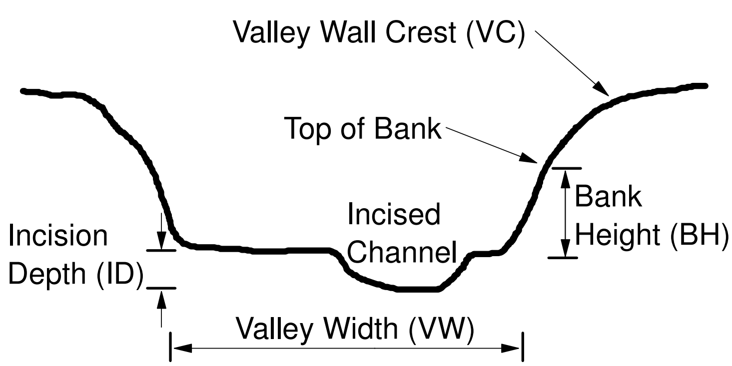
The bank height (BH) is defined as the height from the toe to the top of the bank as determined above. This height along with an expected maximum incision depth (ID) are added together to define the maximum bank height. The incision depth can be calculated using sediment transport procedures; however, this is a complicated analysis. Furthermore, future changes in watershed conditions complicate the prediction of long term conditions. For purposes of this methodology, the incision depth should be assumed to be 5 ft.

Step 2. Calculate the potential bank widening

The amount of bank widening is then defined by a 2H:1V bank slope given the overall bank height.

Step 3. Account for potential lateral migration

To account for future lateral migration a minimum of one valley floor width should then be added to the potential bank widening. The total setback will then be equal to 2*(BH+ID)+1VW measured from the toe of slope for each side.



Erosion Setback is the greater of:
2 x (BH + ID) + 1VW
or VC + 50

Figure 4. Erosion setback definition sketch.

Step 4. Minimum setback distance

The minimum setback distance should extend out past the valley wall crest (VC) by at least 50 ft.

Step 5. Tabulate and/or plot the prudent line

The prudent line for erosion resistant materials is based on an enveloping curve considering the greater of (1) the 100-year floodplain, (2) the calculated setback based on bank slope and height considerations, or (3) the minimum allowable setback based on valley wall crest plus 50 ft.

3.4 Vertical Considerations

Even though the prudent line was developed considering primarily lateral migration, it is important to note that the prudent line also has a vertical component creating a prudent line window. **Figure 5** represents a schematic of a typical stream cross section with the vertical extent of the prudent line shown. The potential lateral migration of the channel, as calculation above, defines the prudent line right-of-way. Using a minimum 2:1 sideslope and 5 ft minimum incision depth, a window of potential erosion can be defined that might occur in the channel cross section.

Infrastructure (i.e., bridges, sanitary sewers, water lines, utilities) that lie outside the window are assumed to be generally consistent with the prudent line. New infrastructure should not be proposed within this window. Existing infrastructure that lies within this window may need to be relocated or protected. Storm sewer outlets may be located within the prudent line window, but may need periodic maintenance (either lengthening or shortening pipe) as the channel migrates.

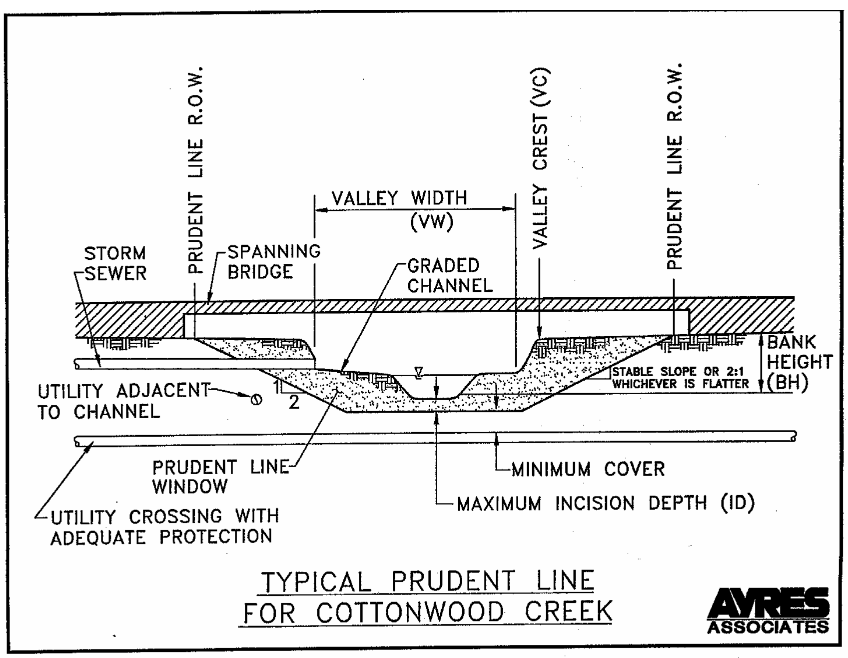


Figure 5. Schematic of typical stream cross section depicting prudent line window.

3.5 Maintenance Line

To insure long term performance of the prudent line, a maintenance line should be established inside the prudent line. The recommended maintenance line is equal to one-half the prudent line. This will provide adequate time to analyze, design and construct potential countermeasures to protect the prudent line if channel migration is greater than expected.

3.6 Sketching the Prudent Line

Given the offset distances calculated above, the prudent line can be drawn along the channel. It is important to recognize that the final location of the prudent line will require engineering judgement and a general understanding of the dynamic nature of alluvial channels. For example, channel bend geometry can change rapidly, including downstream migration of the bendway and/or a cutoff of the bend. Therefore, special consideration should be given to sketching the prudent line along reaches that are highly sinuous with sharp bends. It may be appropriate to draw the prudent line as a tangent line from the outside of one bend to the outside of the next, rather than paralleling the top of bank and forcing the prudent line to follow the bend sinuosity based on the offset distance.

If subreaches are used to define different offsets along a channel, abrupt changes from one reach to the next should be avoided. A gradual transition should always be provided, allowing the channel adequate room to adjust within the defined boundary. Areas around tributary confluences should also be carefully reviewed, to account for channel dynamics in these areas.

In contrast, if areas of competent, non-erodible material are exposed along the channel bank, it may be acceptable to reduce the size of the prudent line area. Similarly, if reaches of riprap or other bank protection exist that are in good condition, well maintained, and designed to survive a large flood, the prudent line may also be adjusted.

If legal descriptions of the prudent line are required, the final prudent line location should be defined as a series of offset tangent lines with distance and bearing descriptions.

3.7 Sediment Deposition Issues

The prudent line as outlined above is based on a channel reach that is experiencing a deficit of sediment, resulting in erosion and channel migration that could endanger adjacent property. However, a reach experiencing sediment deposition will also experience change over time resulting in unexpected channel migration, flooding and potential damage. Examples of areas where sediment deposition could be an issue include reaches upstream of a constricted road crossing, at a sudden reduction in channel slope, downstream of extensively degrading or incising reaches, or on an alluvial fan or other topographic feature that has promoted sediment deposition over time.

If sediment deposition is significant and begins to fill existing channel conveyances, it is possible that a new, radically different channel alignment may develop. The analysis of historic aerial photography may adequately define the various paths that a channel has taken over time, allowing definition of a prudent line. However, such a boundary would likely be quite large, and requires specialized knowledge to accurately define. Furthermore, based on the typically large offsets required to define a prudent line in a deposition area, the prudent line concept is typically not a cost effective or desirable approach in these basins. Maintenance activities to keep a channel defined and functional may be the preferred approach in a sediment depositional area, rather than a prudent line application.