| **FACTORS INFLUENCING THE LIKELIHOOD OF INITIATION OF INTERNAL EROSION OF EMBANKMENT INTO FOUNDATION** | **DATE: JULY 2012** |
|---|---|

**The following factors from the table for Internal Erosion Through an Embankment Dam also apply to this category of Internal Erosion of Embankment into Foundation, as they relate primarily to the potential for seepage and internal erosion in the embankment portion of the seepage path:**

- Seepage
- Soil Erodibility
- Sinkholes or depressions
- Construction
- Impermeable zone width
- Foundation preparation of surface irregularities (foundation of the impermeable zone) and construction of first lifts on foundation
- Embankment zoning and overall geometry
- General quality of construction and quality control (also see construction as related to compaction above)
- Impermeable material characteristics
- Age of dam / length of service

**In general, the factors from the table for Internal Erosion Through an Embankment Dam that relate to settlement and other causes of "defects" in an embankment were not included in this table given the improbability that an embankment defect would line up with a foundation defect.**

**However, if aligned defects are a consideration for a given embankment/foundation internal erosion failure mode being evaluated, consider the applicability of those factors as well.**

**FACTORS INFLUENCING THE LIKELIHOOD OF INITIATION OF INTERNAL EROSION OF EMBANKMENT INTO FOUNDATION** **DATE: JULY 2012**

| **Factor** | **Influence on Likelihood / Relative to Reclamation Historical Base Rates (see notes)** | | | **Comments** |
|---|---|---|---|---|
| | **Less Likely** | **Neutral** | **More Likely** | |
| Foundation surface treatment measures | Dental concrete used to shape bedrock surfaces; slush grouting used to seal surface joints and fractures | Careful surface cleaning, but no dental concrete or slush grouting | No attention to foundation surface cleanup; no surface treatment measures | Careful attention to the treatment of foundation defects reduces the potential that seepage can attack the embankment/foundation contact |
| Initial fill placement on foundation | Plastic material placed on foundation surface; thin lifts; rolling with rubber tired equipment | Careful compaction, but no mention of more plastic soils | Thick lifts used; limited compaction; no mention of more plastic soils | The use of a plastic core material, perhaps placed wet of optimum, on the foundation surface reduces potential for erosion |
| Foundation grouting | Multiple row grout curtain in rock foundation<br><br>Blanket grouting performed | Single row grout curtain in rock foundation; typical USBR grouting practices employed | No grouting of bedrock foundation that appears to have potential for seepage | Improperly designed and executed grouting programs can lead to windows for concentrated flow and high gradients near the top of the curtain<br><br>Also consider the orientation of grout holes with respect to the discontinuities, as well as the robustness of closure criteria and the relative grout takes |

| **FACTORS INFLUENCING THE LIKELIHOOD OF INITIATION OF INTERNAL EROSION OF EMBANKMENT INTO FOUNDATION** | | | | **DATE: JULY 2012** |
|---|---|---|---|---|
| **Factor** | **Influence on Likelihood / Relative to Reclamation Historical Base Rates (see notes)** | | | **Comments** |
| | **Less Likely** | **Neutral** | **More Likely** | |
| Presence and orientation of bedrock discontinuities | Minimal rock jointing and fracturing reported<br><br>Much less likely if bedrock reported to be massive | Some bedrock discontinuities reported, but no widespread areas of fracturing/jointing | Embankment footprint contains large areas of significantly jointed or fractured bedrock, or contains prominent continuous joints or fracture patterns oriented upstream to downstream | The continuity of any bedrock feature such as a fault, joint, or fracture system is an important factor as to whether a seepage path will develop |
| Nature of bedrock discontinuities | Bedrock joints and fractures reported or observed to be tight/healed<br><br>Discontinuity infillings are erodible | Bedrock joints or fractures reported or observed to be relatively tight, infilled, or open only a few millimeters | Bedrock joints and fractures reported or observed to be open several millimeters to centimeters or larger | Also consider the level of detailed documentation (or lack thereof) of the nature of the discontinuities |
| Presence of open-work foundation soils | No open-work foundation soils | Some coarse-grained deposits exist, but of questionable continuity and not particularly high porosity | Continuous layers of high porosity or open-work gravels and/or cobbles or talus | Also consider the level of detailed documentation (or lack thereof) of the nature of any open-work deposits |
| Presence of karstic features | Much less likely – no karstic features present | Karstic features are at depth or were recognized and properly treated | Features such as solution channels, brecciated zones, ancient chimneys and similar were present beneath dam footprint, with marginal treatment measures | |

<u>Notes on use of Table:</u>

1. Table is intended to provide guidance in addition to historical base rates of initiation of internal erosion. The neutral factors listed in the table would correspond to average base rates. Neutral factors do not imply a 50% probability. In general for a given Reclamation dam, there would be justification to select a probability of initiation of internal erosion higher than historical base rates if that dam was characterized by multiple "more likely" factors listed above; and conversely, there would be justification to select a probability of initiation of internal erosion lower than historical base rates if that dam was characterized by multiple "less likely" factors. Whether the estimated probability of initiation of internal erosion is higher, lower or near the historical base rate, the justification for the estimated probability must be documented. This table provides some guidance for that justification.

2. Some factors listed on the table apply to all internal erosion mechanisms (backward erosion piping, internal migration, scour, suffusion/suffosion) while some factors might only apply to one mechanism.

3. Some factors listed on the table are more critical to initiation of internal erosion than others. In general, more influential factors are listed towards the top of the table and less influential factors are listed towards the bottom.

4. For some factors, the "Less likely" column also includes factors that would make the probability of initiation "much less likely."

5. Expert guidance is critical for interpreting observations at a dam and making judgments that relate performance of a specific dam to historical base rates of internal erosion.

<u>References:</u>

Fell, R. and C.F. Wan (2004), "Methods for Estimating the Probability of Failure of Embankment Dams by Internal Erosion and Piping in the Foundation and from Embankment to Foundation," University of New South Wales, Sydney, Australia. UNICIV Report 436. January 2004.

"A Method for Estimating Probabilities of Failure of Embankment Dams due to Internal Erosion," USACE Internal Erosion Toolbox, Best Practices Guidance Document, Final Draft, January 2010.