Erosion and Geomorphology

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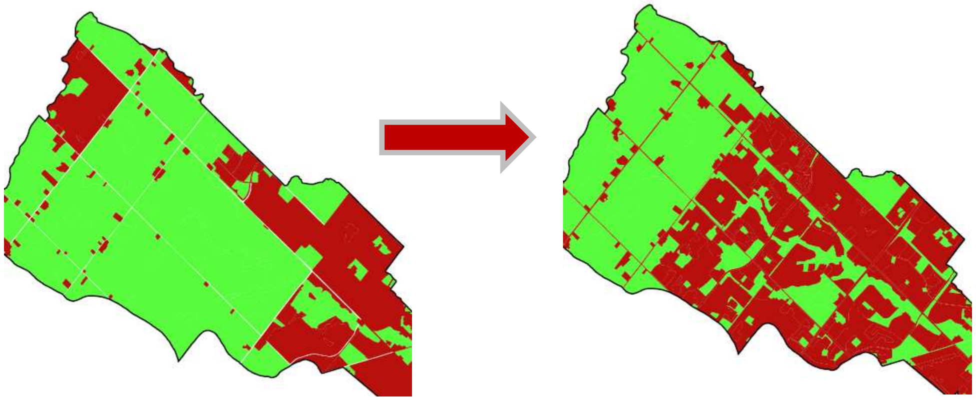
Conservation TORONTO AND REGION

CVC CREDIT VALLEY CONSERVATION

Credit Valley Conservation

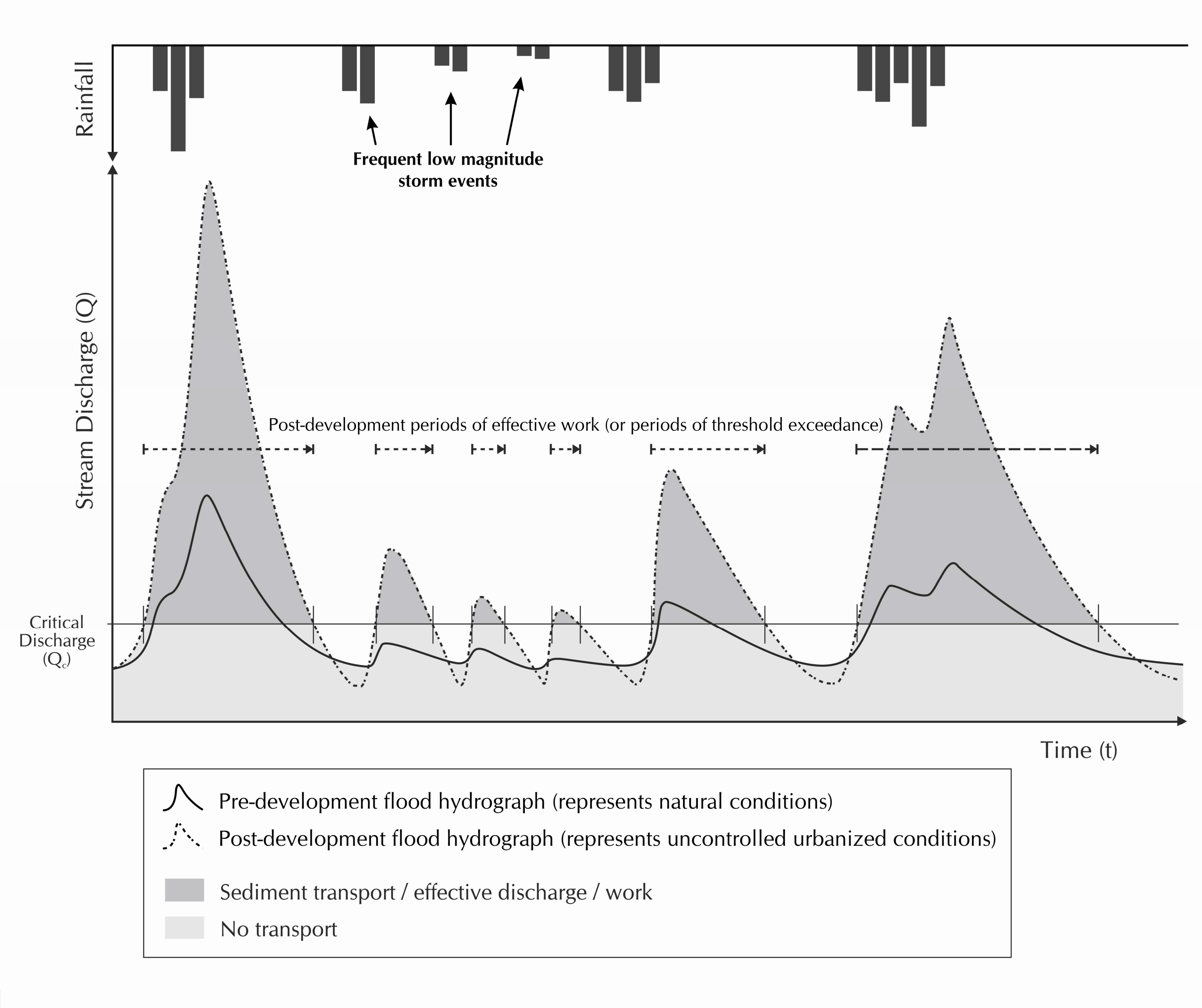
Unmitigated Urbanization

- **Land use changes influence the flow and sediment regimes of watercourses within the affected catchment**



- **Unmitigated urbanization leads to increased runoff and greater peak flows**
  - unwanted erosion
  - decrease in channel stability

Unmitigated Urbanization

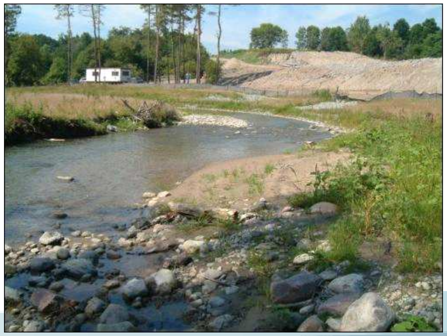


Mitigation Strategies

- Most post-development mitigation strategies rely on retention and detention within stormwater management (SWM) ponds
- A retention basin (a.k.a. wet pond, or wet detention basin) has a permanent pool of water incorporated within its design
- Overall SWM design should be based on matching specific post- to pre-development flow conditions

Mitigation Strategies

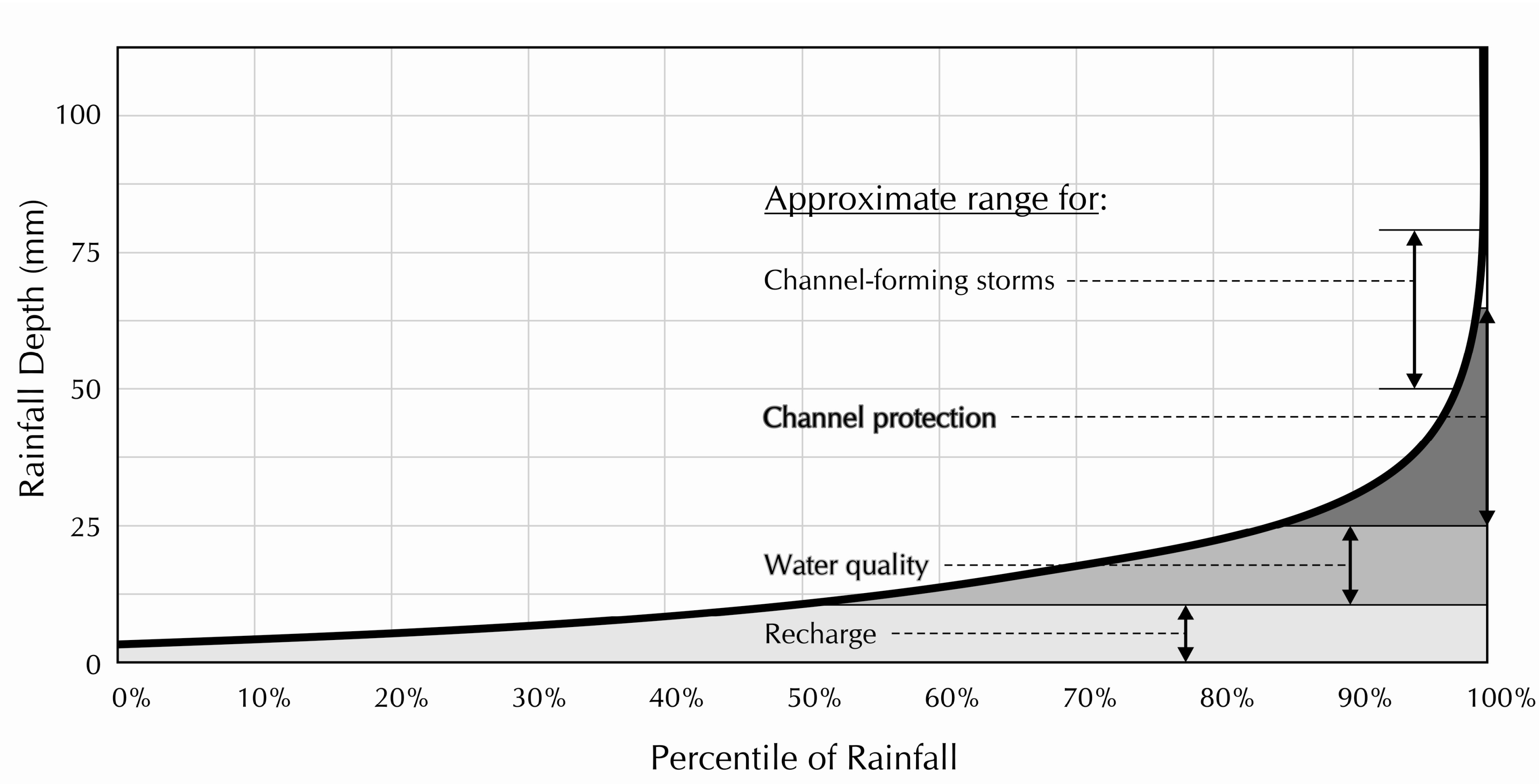
- **Match the post- peak flow of a given return event to pre-development conditions**
  - one of the first methods, still applied today
  - shave, or distribute flows over a greater duration
  - choose an event to correlate with bankfull flow (e.g., event with 1.5- to 2-year return period)
  - assumes that significant threshold conditions for channel change occur at, or around, bankfull



Mitigation Strategies

- **Within southern Ontario, data suggests that capacity of watercourses to assimilate increased discharge without unwanted erosion or geomorphological adjustment is usually well below bankfull, or 2-year return**
  - shaving flows can lead to longer periods where the threshold is exceeded, thus exacerbating erosion

Mitigation Strategies

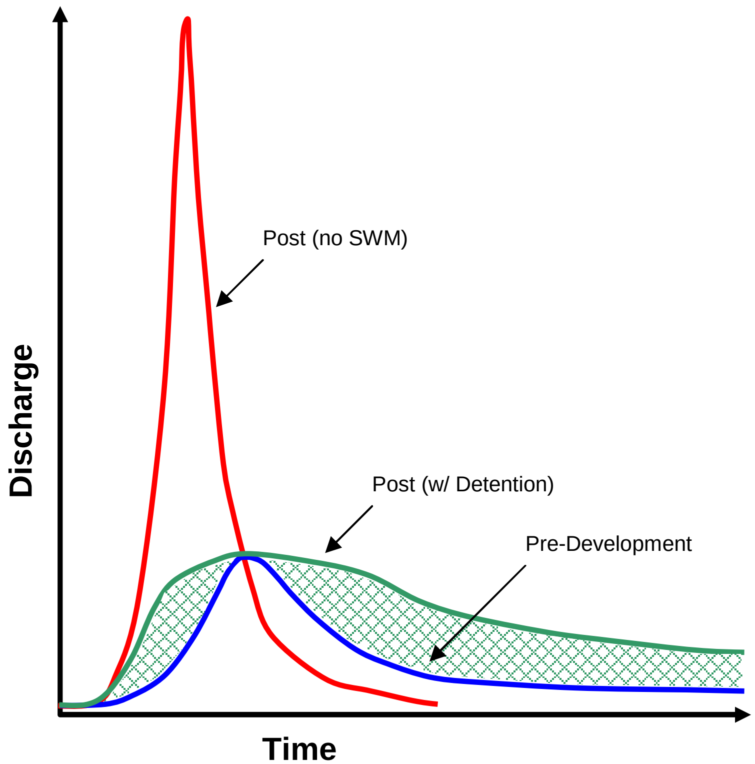


Idealized allocation of rainfall events within an integrated SWM approach (Maryland Stormwater Management Program, Comstock and Wallis, 2003) - all ranges are considered to be approximate

Mitigation Strategies

- **Concern amongst Conservation Authorities within the GTA and other parts of southern Ontario**
  - generic retention-based approaches are not capable of effectively addressing erosion mitigation, especially in sensitive systems
  - meeting these targets in post- to pre-development scenarios is impractical with detention approaches alone

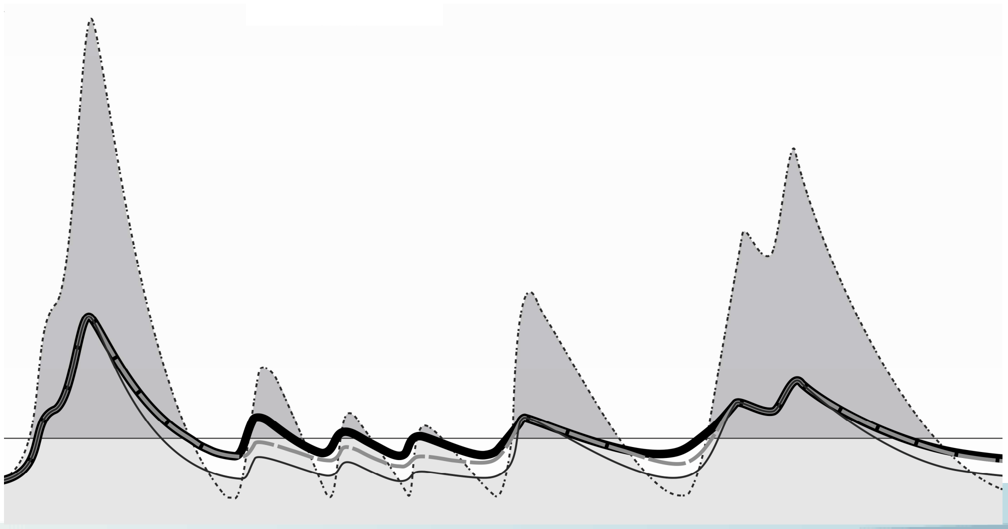
Concerns with Detention Approach



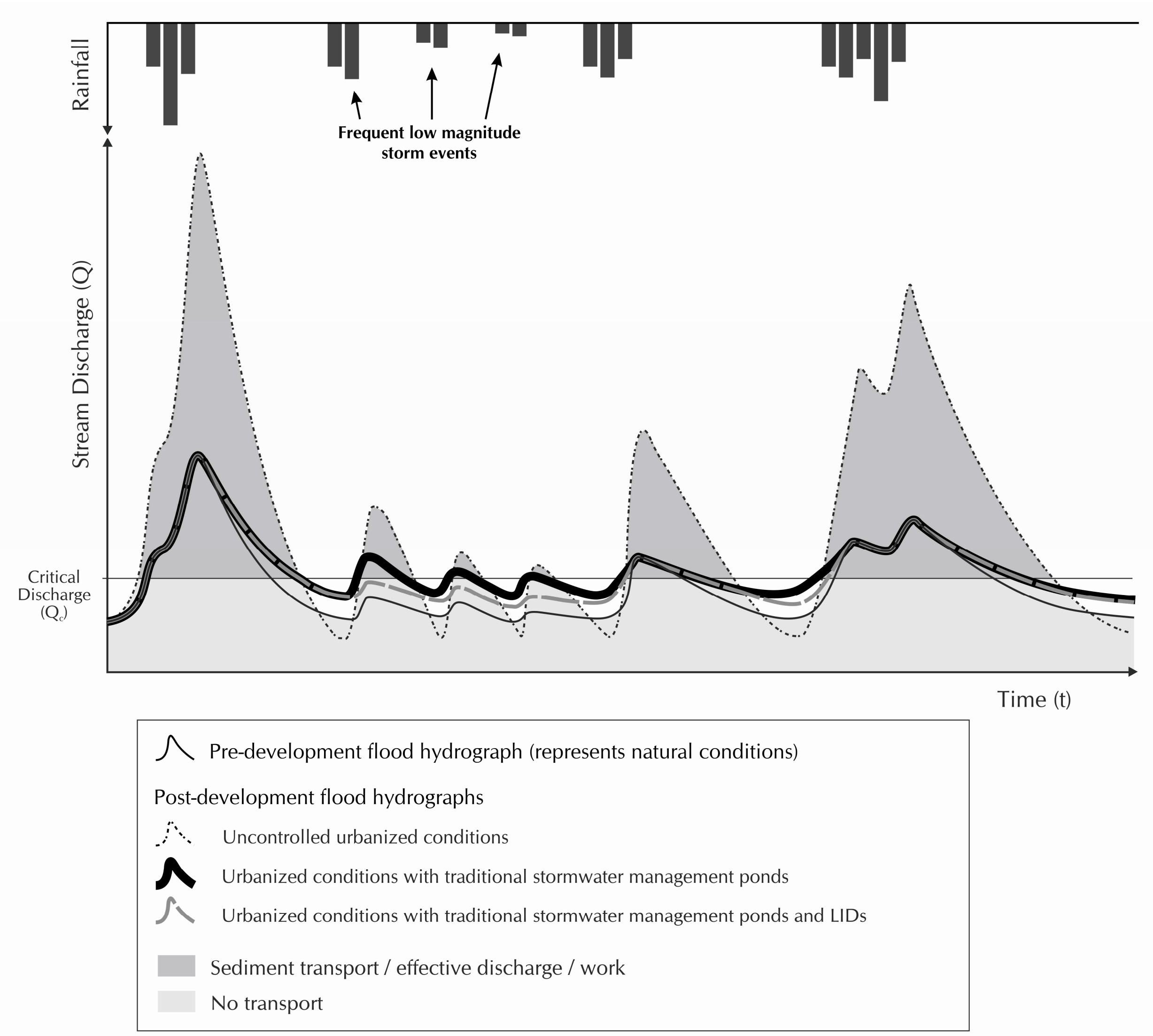
- there may not be a “safe” way to discharge 500% more runoff
- cumulative effects of watershed development are not managed
- design assumptions are unrealistic
- streamflow regimes are still being altered
- does not mitigate loss of natural flow pathways or temperature impacts

Mitigation Strategies

- **Agencies and <u>practitioners</u> have moved to approaches including site-specific erosion or entrainment thresholds, in combination with post- to pre-development exceedance analysis**
  - adoption of these approaches has gone a long way to address instream erosion issues



Mitigation Strategies



Mitigation Strategies

- **Evidence suggests that on-site control should be in the order of 7-15 mm, corresponding approximately to the 6-month return event**
  - this is a general range that likely fluctuates given the local geology and soil conditions within a given jurisdiction
- **Given technical constraints, it is likely that on-site control of 5 mm is more feasible (infiltration and/or reuse)**

Conservation Toronto and Region

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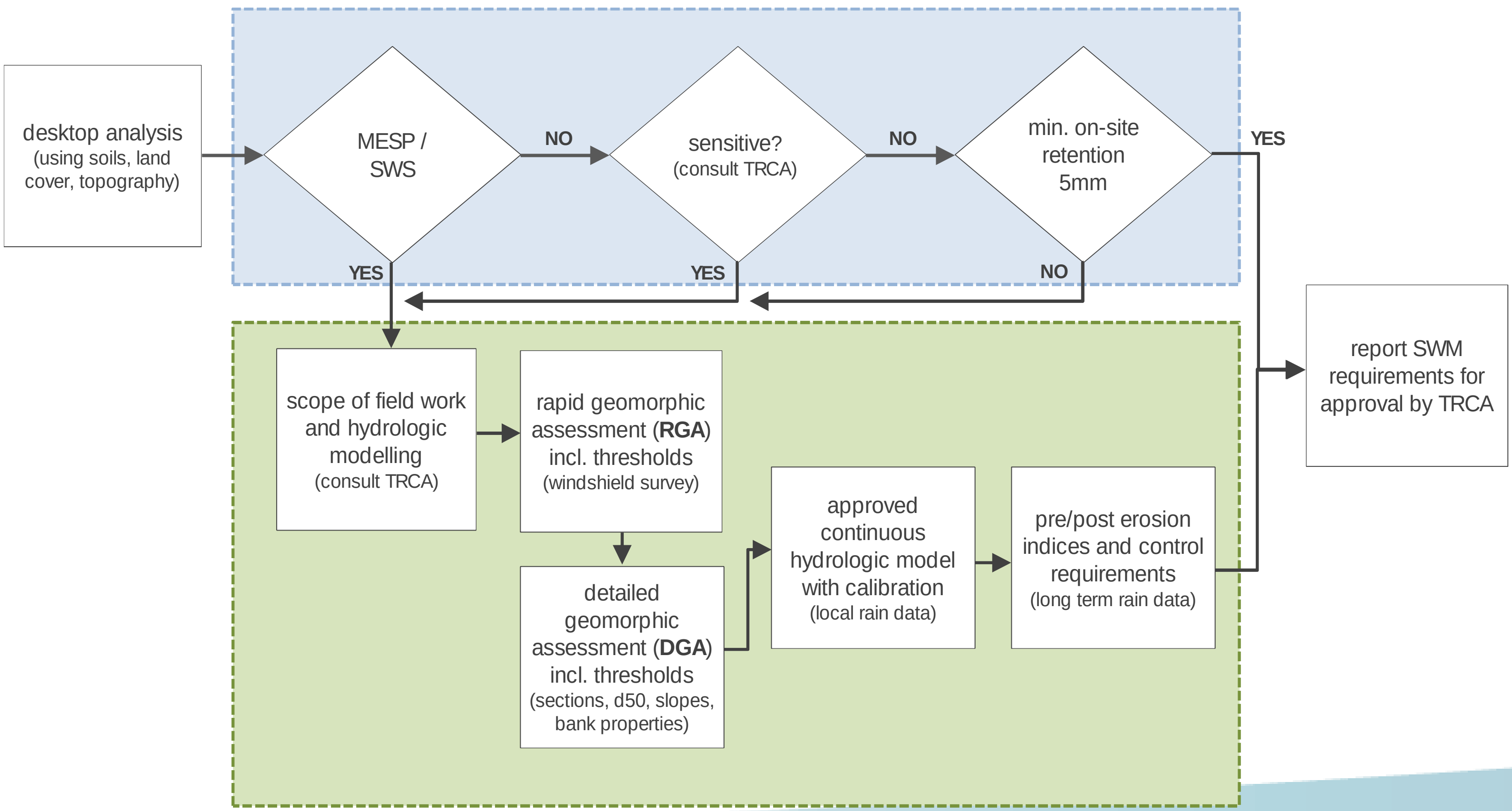
Erosion Analysis – Step-by-Step

Defining erosion mitigation practices for a proposed development



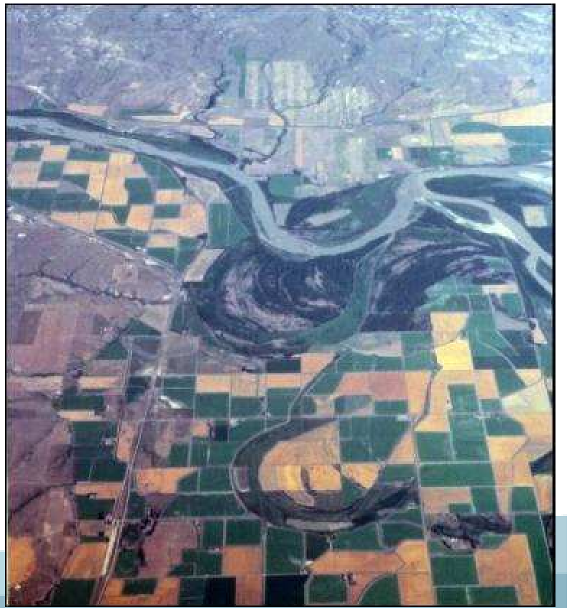
Erosion Analysis – Step-by-Step*

1. **Geographical Extent of Analysis**
2. **Reach Delineation**
3. **Rapid Geomorphic Assessment (RGA)**
4. **Detailed Geomorphic Assessment (DGA)**
5. **Erosion Thresholds**
6. **Hydrologic Modelling**
7. **Erosion Indices**

* Together these elements provide the information necessary to compare pre- and post-development scenarios, and define the measures required to effectively mitigate erosion-related impacts of development

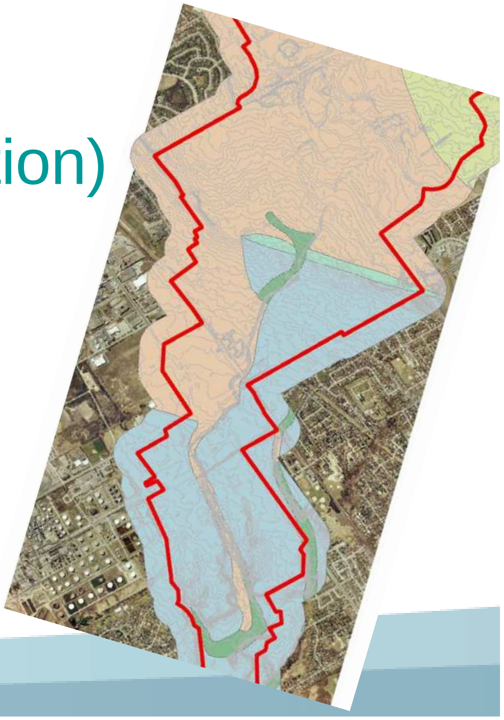
Geographical Extent of Analysis

- **Impacts from changes to hydrology can extend downstream from development area**
- **Extent of impact is highly variable**
  - function of watercourse sensitivity
  - system's capacity to assimilate adjustments in flow regime
- **For simple, single pond systems:**
  - defined as length of channel downstream of development next major confluence



Reach Delineation

- **Divide a watershed into homogeneous channel segments, using:**
  - aerial photography
  - surficial geology
  - topographic mapping
- **Indicators for reach breaks include:**
  - land surface cover (land use, vegetation)
  - drainage network (confluences)
  - soil types
  - abrupt changes in slope
  - road network (crossings, outfalls)



Rapid Geomorphic Assessment

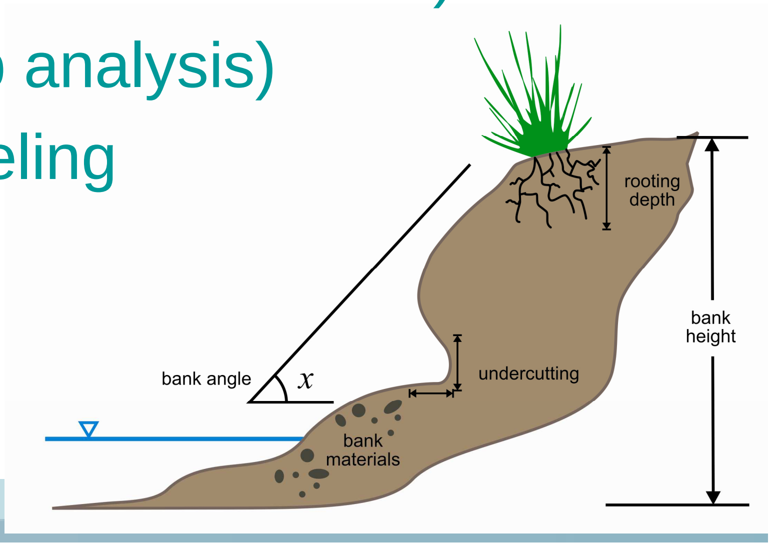
- **Identify and evaluate sensitive reaches**
- **Factors affecting sensitivity include:**
  - stability
  - physiography
  - bed and bank materials
  - historic impacts or form
  - channel dimensions

- **RGA is a standard, objective, in-field technique***

** Stormwater Management Planning and Design Manual (MOE, 2003)*

Detailed Geomorphic Assessment

- **Determine whether hydrologic changes resulting from land use change will result in increased or decreased erosion**
- **Calculate a proxy or index for erosion, using:**
  - channel geometry (field measurement)
  - sediment particle sizes (field measurement)
  - erosion thresholds (desktop analysis)
  - continuous hydrologic modeling



Erosion Thresholds

- **Determine a channel's critical discharge at which its sediment should be entrained or transported**
- **Calculation of a threshold requires:**
  - mean channel slope
  - median particle size
  - reference cross-section dimensions, including any terraces and the floodplain width
  - visual assessment of roughness factors

Hydrologic Modelling

- **Method for assessing post- to pre-development erosion potential**
  - accounts for impacts of pond function and antecedent hydrologic conditions on instream erosion
  - allows for interaction of multiple ponds and examination of potential cumulative impacts
- **Model must be calibrated and verified with meteorological data and pre- and post-development hydrographs**
- **Need to collect data if streamflow and precipitation data are not available**

Erosion Indices

- **Aim to match the frequency of exceedance and cumulative effective work (or other surrogate) in pre- and post-development conditions**
- **Where erosion cannot be matched using end-of-pipe approaches, other mitigation measures may be required**
  - if deemed necessary, these measures must be developed in consultation with the TRCA
- **In some very sensitive systems, or where impacts have already occurred, a level of over-control may be required**

Erosion Indices

- **Cumulative Time of Exceedance**
  - provides a simple comparison as a first cut
  - does not provide information on the work or erosive force of flows once thresholds are exceeded
  - more stringent assessment required
- **Cumulative Erosion Index (*E_i*)**

$$E_i = \sum (V_t - V_c)\Delta t$$

Where: V_t is velocity in the channel at time t

V_c is critical velocity above which entrainment will occur

Δt is the time step

Erosion Indices

- **Cumulative Effective Work Index (*W_i*)**

$$W_i = \sum(\tau - \tau_c)V\Delta t$$

Where: τ is shear stress at time t

τ_c is critical shear stress for either the bed or the bank

V is mean channel velocity

Δt is the time step

- **Calculating indices requires a *continuous* time series of discharge and a table relating discharge to excess shear stress**
  - Calculating ***W_i*** also requires mean channel velocity at various depths

Results Reporting Framework

- **The following checklist* should be used as a minimum guideline for development proposals:**
  - mapping of zone of influence, channel network, reach breaks, pond locations, and sensitive reaches
  - mapping of soils, current land use and road network
  - RGAs for all reaches, reach-by-reach descriptions including physical conditions, sensitivity, and systematic adjustments/dominant processes
  - Photographic support of RGA analysis
  - (cont'd)

* *Stormwater Management Criteria (TRCA, 2012)* provides full list of submission requirements and related procedural details

Results Reporting Framework

- **(cont'd)**
  - Detailed field assessment of sensitive reaches
  - Summary of cross-section geometry
  - Quantification of erosion threshold(s)
  - Calibrated and verified continuous hydrologic modeling
  - Cumulative time of exceedance for pre- and post- development conditions, and cumulative effective shear stress and effective work