DELFT 3-D MODELING: MODEL DESIGN, SETUP, AND ANALYSIS

Each experiment starts from the initial condition of a straight channel 10 km long, with an adjacent 3300 m wide floodplain (Figure DR1). The floodplain is separated from the channel by a levee 400 m wide, 3 m tall, and 10 km long. Both the channel and floodplain have the same slope of $5 \times 10^{-4}$. The initial cross-sectionally averaged width and depth of the channel are 250 m and 3 m, respectively, chosen to be in equilibrium with the bankfull discharge. The channel has a normalized super-elevation (levee height divided by channel depth) of 1 to insure that avulsions occur in each simulation. To simulate nonuniform floodplain topography we randomly place Gaussian-shaped, non-overlapping bumps, each ~0.5 m high and 150 m x 150 m in area, over 50% of the floodplain area. Tests showed that model results are generally insensitive to a range of bump heights (0.25-1.0 m) and percent coverage (30-80%).

All runs employ a morphodynamic scale factor of 20. This scale factor is a multiplicative term applied to the erosive or depositional fluxes to/from the bed and is intended to speed up the computation. We tested sensitivity to this parameter and found our results to be insensitive to a value of 20 or less. The incoming flood hydrograph has a high-flow (1900 m$^3$ s$^{-1}$), low-flow (330 m$^3$ s$^{-1}$), and bankfull (750 m$^3$ s$^{-1}$) discharge. The hydrograph is modeled such that each flood is 5 days long (when accounting for the scale factor). Because little morphodynamic change happens at low flow we minimize the length of time between floods. In our runs there are 10 days between each flood, which is enough time to allow for the floodplain to completely drain before the next flood arrives. The channel and floodplain have the same hydraulic roughness with $C = 65$ m$^{1/2}$ s$^{-1}$.

Figure DR1: Planview of model set up. Flow and sediment boundary conditions are specified at the incoming flow boundary, while stage discharge relations are specified downstream. Levee cells closest to the incoming flow boundary are set to ‘dry’ so that the avulsion does not occur close to the boundary creating instabilities.

$R$ is directly observed in each model run. To calculate $T_p$, we track the front of the advancing sediment wedge through time, and $L_p$ is the distance from the avulsion breakout to the end of the model domain. We calculate $T_i$ directly by averaging incision rates at randomly sampled floodplain locations that are experiencing incision (i.e. we ignore areas undergoing no change). We assume $D_i$ is equal to $\frac{1}{2}$ of depth of the parent channel (e.g., superelevation thresholds of Mohrig et al., 2000), and measured the spatial distribution of incision and found that $\alpha \approx 0.5$. 

Table DR1: Results from each model run in this study.

<table>
<thead>
<tr>
<th>Run Number</th>
<th>Grain Size of sand fraction</th>
<th>( \tau_{eq\text{(sand)}} )</th>
<th>Areal percentage of floodplain that is sand</th>
<th>Alpha</th>
<th>( D_c )</th>
<th>( \bar{P} )</th>
<th>( \bar{I} )</th>
<th>( T_p \text{(days)} )</th>
<th>( T_i \text{(days)} )</th>
<th>( R )</th>
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DATA FROM ANCIENT DEPOSITS

Classifying Avulsion Stratigraphy

Avulsion stratigraphy surrounding channel-belt sand bodies in well-exposed outcrop belts was observed in the Ferris and Willwood formations and Shire Member of the Wasatch Formation. Avulsion stratigraphy was classified as either stratigraphically transitional or stratigraphically abrupt following Jones and Hajek (2007). Floodplain deposits subjacent to stratigraphically transitional channel-belt deposits show generally progradational successions with evidence of increasing sedimentation rates up-section, including, for example, more, coarser, and/or thicker crevasse-splay deposits and weaker paleosol development than seen in characteristic distal or far-field floodplain deposits. Stratigraphically abrupt channel-belt deposits are juxtaposed directly atop distal floodplain deposits with no evidence for intervening proximal-overbank deposition. We note that channel enlargement upon successful avulsion can lead to the partial erosion of underlying proximal-overbank deposits (e.g., Smith et al., 1989); consequently we only include sand bodies where both channels and adjacent floodplain deposits are extensively exposed in outcrop.

Figure DR2 shows an example section through two Shire Member channel deposits. Tables DR2-DR4 summarize data for observations from each unit, including the maximum channel-deposit grain size and the maximum grain size of floodplain deposits beneath the channel deposit (typically within approximately one channel-belt thickness beneath the channel deposit). Note that for the Shire Member and Willwood Formation, channel grain-size observed in hand samples approximates the median grain diameter (D50) of bed material. The Ferris Formation D50 of all channels is 1-2 mm, but some channels contain rare pebbles and cobbles (Hajek et al., 2012). Other sedimentological characteristics of each unit are described in the following sections.
Figure DR2 (left). Example measured section from Shire Member channel deposits SM11 and SM08. SM11 is a stratigraphically abrupt deposit (A) with a maximum grain size of silt beneath the channel. SM08 is a stratigraphically transitional avulsion deposit (T) with sandy crevasse-splay deposits beneath the channel.

Figure DR3 (right). Map of portions of Wyoming and Colorado, USA showing channel-deposit localities from this study: the Willwood Formation (red, Bighorn Basin, WY), Ferris Formation (yellow, Hanna Basin, WY), and Shire Member of the Wasatch Formation (blue, Piceance Basin, CO). Map available at https://mapsengine.google.com/map/edit?mid=zyZWlaO26o9g.k_Mm6yNohDFg
Field Areas

Shire Member of the Wasatch Formation

The Eocene Shire Member of the Wasatch Formation is a fluvial unit exposed in the Piceance Basin, western Colorado (Foreman et al., 2012; Lorenz and Nadon, 2002; Figure DR4). The Shire Member is characterized by dominantly medium-sand channel-belt deposits and silt-and-clay-rich floodplain mudstones with moderate- to well-developed paleosol horizons (e.g., Foreman et al., 2012; Mohrig et al., 2000). Data presented here were collected during 2011 and 2012.

Table DR2: Data for Shire Member observations. T = Transitional avulsion stratigraphy, A = stratigraphically abrupt avulsion stratigraphy. Channel grain size abbreviations indicate sand-class size (F = fine, M = medium, modified by upper (U) or lower (L)).

<table>
<thead>
<tr>
<th>ID</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Channel grain size</th>
<th>Max. overbank grain size beneath channel</th>
<th>Avulsion stratigraphy</th>
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</thead>
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<td>39° 26’ 35.68&quot;</td>
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<tr>
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<td>-108° 7’ 25.9”</td>
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<td>Fine sand</td>
<td>A</td>
</tr>
<tr>
<td>SM03</td>
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<td>-108° 7’ 25.9”</td>
<td>ML</td>
<td>Silt</td>
<td>A</td>
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<td>FL</td>
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</table>
**Willwood Formation**

The Paleocene-Eocene Willwood Formation is exposed in the Bighorn Basin, Wyoming (Figure DR3) and comprises medium-to-coarse-sand channel deposits set in clay-rich floodplain-mudstone deposits with prominent paleosol horizons (e.g., Kraus, 2001; Kraus and Wells, 1999). Avulsion stratigraphic data come from Jones (2007) and Jones and Hajek (2007). Note that only deposits of trunk channels (c.f. Kraus) are included in this analysis.

Table DR3: Data for Willwood Formation observations. T = transitional avulsion stratigraphy, A = stratigraphically abrupt avulsion stratigraphy.

<table>
<thead>
<tr>
<th>ID</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Channel grain size</th>
<th>Max. overbank grain size beneath channel</th>
<th>Avulsion stratigraphy</th>
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<td>Silt</td>
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<td>Fine sand</td>
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</tr>
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</table>
**Ferris Formation**

The Maastrichtian/Paleocene Ferris Formation crops out in the northern Hanna Basin, Wyoming (Figure DR3), where it dips nearly 80º to the south, exposing a cross-section of the paleo-basin fill across the present-day land surface (Hajek et al., 2012; Hajek et al., 2010). Channel-belt sand bodies primarily comprise coarse sand and are surrounded by very clay-rich, carbonaceous floodplain mudstone deposits. Avulsion stratigraphy data presented here was documented during channel mapping (Hajek, 2009), when individual channel bases were tracked along the outcrop exposure.

Table DR4: Data for Ferris Formation observations. T = transitional avulsion stratigraphy, A = stratigraphically abrupt avulsion stratigraphy. Note that channel grain size for the Ferris Formation represents the maximum observed grain size in mm, including measurement from small numbers of pebbles and cobbles found within some sand bodies (from Hajek et al., 2012). Ferris channel bed-material deposits comprise dominantly 1-2 mm sand.

<table>
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