Flooding , Erosion, and Sedimentation Issues Related to Sand and Gravel Mining

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I. Overview

My name is William Dupre', and I live in Harris County. I am presently Professor Emeritus at the University of Houston, with broad experience with geologic hazards and risk assessment.

- *Ph.D. (Geology), Stanford University; M.S. (Hydrology), Stanford University; M.A., (Geology), University of Texas at Austin; B.S.(Geology), University of Texas at Austin.*
- *45 years of teaching and research experience at Wesleyan University (2 yrs.) and the University of Houston (43 yrs.).*
- *Conducted research on geologic hazards in California (earthquake risk), Alaska (impacts of offshore drilling), and Texas (river flooding and hurricane impact)*
- *Consulted for the U.S. Geological Survey, NOAA, Dept. of Justice, and U.S. Corps of Engineers, as well as numerous companies.*
- *Currently doing research on the impact of land use changes on Texas rivers and coastal regions.*
- *Received national award for Outstanding Public Service for workshops and lectures in the Houston region on issues of flooding during Hurricane Harvey.*

My report is submitted in support of the petition filed with the Texas Commission on Environmental Quality on June 23, 2020 by Lake Houston Area Grassroots Flood Prevention Initiative to establish best management practices (BMP's) for commercial sand mining and other lawful purposes within the San Jacinto River Watershed (SJRW). This is driven in part by the rapidly increasing number of sand mines which have sought and obtained TCEQ operating permits. My focus is on the issues of flooding, erosion, and sedimentation related to sand and gravel mines in the San Jacinto River basin, and will not include discussion of other potential (but important) impacts of sand and gravel mining, such as air pollution, noise, traffic, etc.

II. Key Issues

Mining and Flooding:

With one exception, <u>all</u> sand mines in the San Jacinto River Watershed are located partially or completely within the **regulatory floodway,** an area delineated by FEMA as having the highest potential for flooding (and erosion) along major waterways. "[T]he floodway is an extremely hazardous area due to the velocity of flood waters which carry debris, potential projectiles and erosion potential…". (Montgomery County Flood Plain Management Regulations, 2014, p.25)

Communities are required to regulate development (including sand mines and quarries) in these floodways to ensure there is no increase in upstream flood elevations (FEMA, 2020). The result of partitioning large areas of the floodway from rising floodwaters by levees and dikes can result in increased flooding of adjacent areas. Flood-induced breaches in levees can also add to the problems of flooding, erosion, and sedimentation downstream (discussed below)

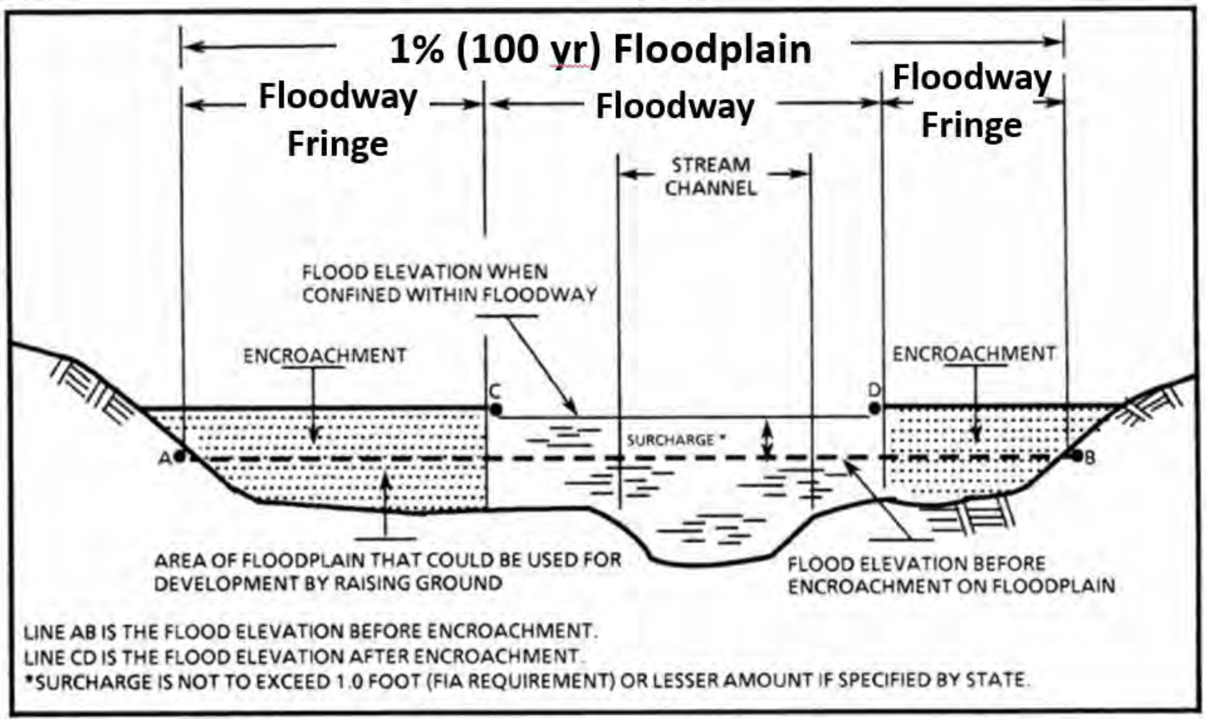

Figure 1. Cross-section illustrating the definition of the regulatory floodway, floodway fringe, and 1% (100 yr.) floodplain.

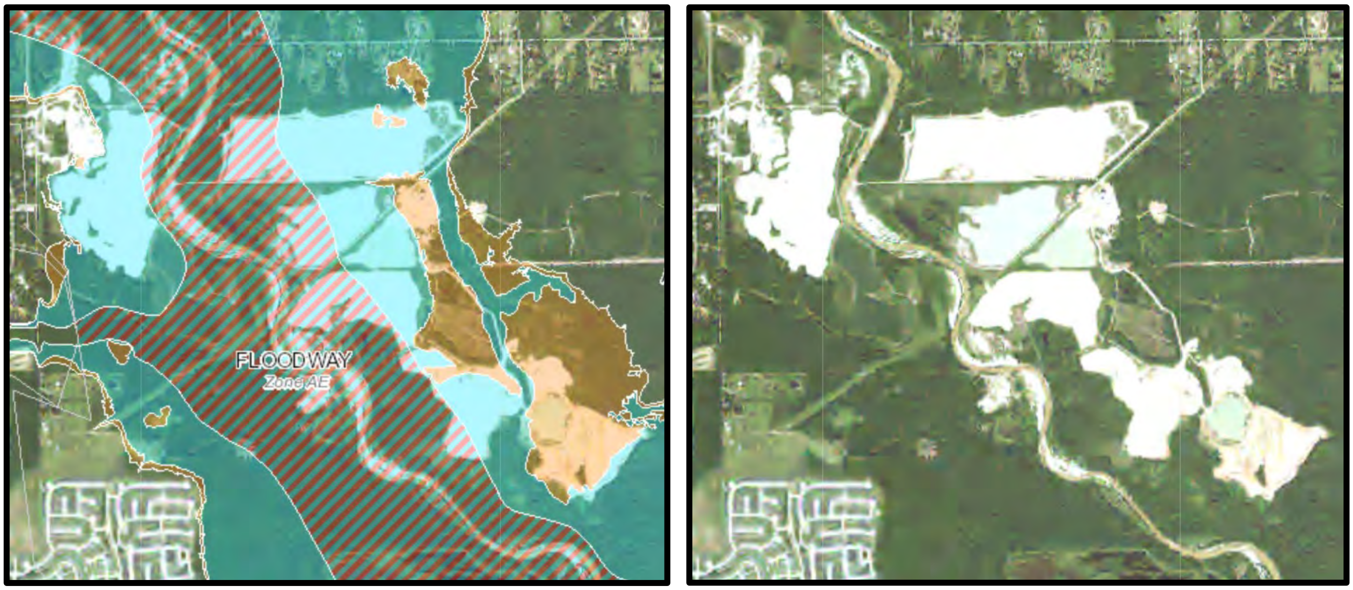

Figure 2: Google images sand mines on the West Fork of the San Jacinto River located on the regulatory floodway and the 1% (100-yr.) floodplain. (*https://hazards-fema.maps.arcgis.com/apps/webappviewer/*)

Erosion and Sedimentation:

> One of the major hazards associated with flooding is *erosion* , thus FEMA (1999) recommended the establishment of Riverine Erosion Hazards Areas (REHA's) be delineated to address requirements in Section 577 of the National Flood Insurance Act (NFIA) of 1994. REHA's delineate areas where erosion or avulsion (sudden changes in the river's course) is likely to result in damage within a specified time period (typically 60 years). This concept has been adopted by counties and cities (e.g. Austin, Texas - COA-WPD, 2013) in states throughout the country, where these areas are now referred to as Channel Migration Zones (CMZ's); see Washington Dept. Ecology (2014) for definitions and methodology.

Erosion not only results in the loss of land, property, and riparian habitats, but it also generates increased sedimentation. According the E.P.A., sediment is the *most common pollutant* in rivers, streams, lakes, and reservoirs, with nearly 70 % of the total sediment in the U.S. the result of *accelerated erosion* from human use of land. A significant source of this human-induced sediment is mining, especially those mines located in river floodplains where unconsolidated sand is most abundant and easily excavated. Potential problems related to erosion and sedimentation exist during all phases of the development of floodplain mines, from exploration and construction to post-mining abandonment.

Levee failures: During the <u>active phase</u> of floodplain mining, the main problem is pit leakage when protective levees (or dikes) are breached, often during floods. Breaches most commonly occur where: 1) the buffer width between the pit and river is too narrow (e.g. Figure 3), 2) the levees are poorly designed and/or maintained, and 3) the depth of the pit is below the depth of the adjacent channel.

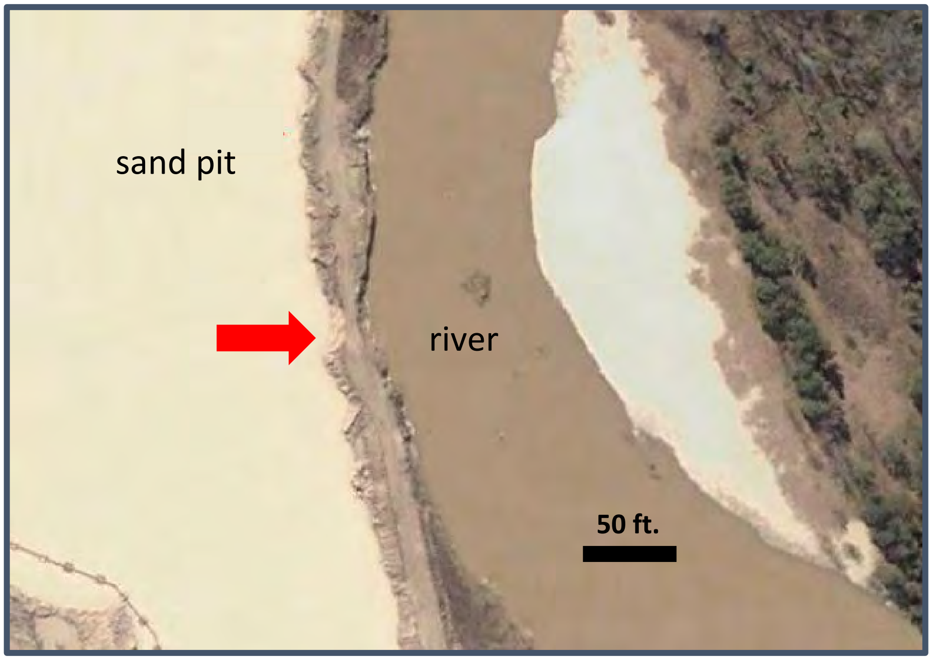

Figure 3: Buffer between West Fork of San Jacinto River and sand pit ~15 ft! Note erosion is occurring on both the river and pit side of the levee. (Google Earth image taken Feb. 2004)

Levee failure in turn can result in flushing of water and pollutants; e.g. sediment, oil spillage, chlorides, sulfates, TDS (total dissolved solids), pH, DO (dissolved oxygen), and cyanobacteria onto and into adjacent land, wetlands, and waterways. Additional pollution can occur by erosion-induced pipeline failures. Floodplain pits typically intercept the groundwater table; thus, groundwater pollution can occur if pit waters become contaminated. Pumping in the pit can also result in lowering of adjacent water tables.

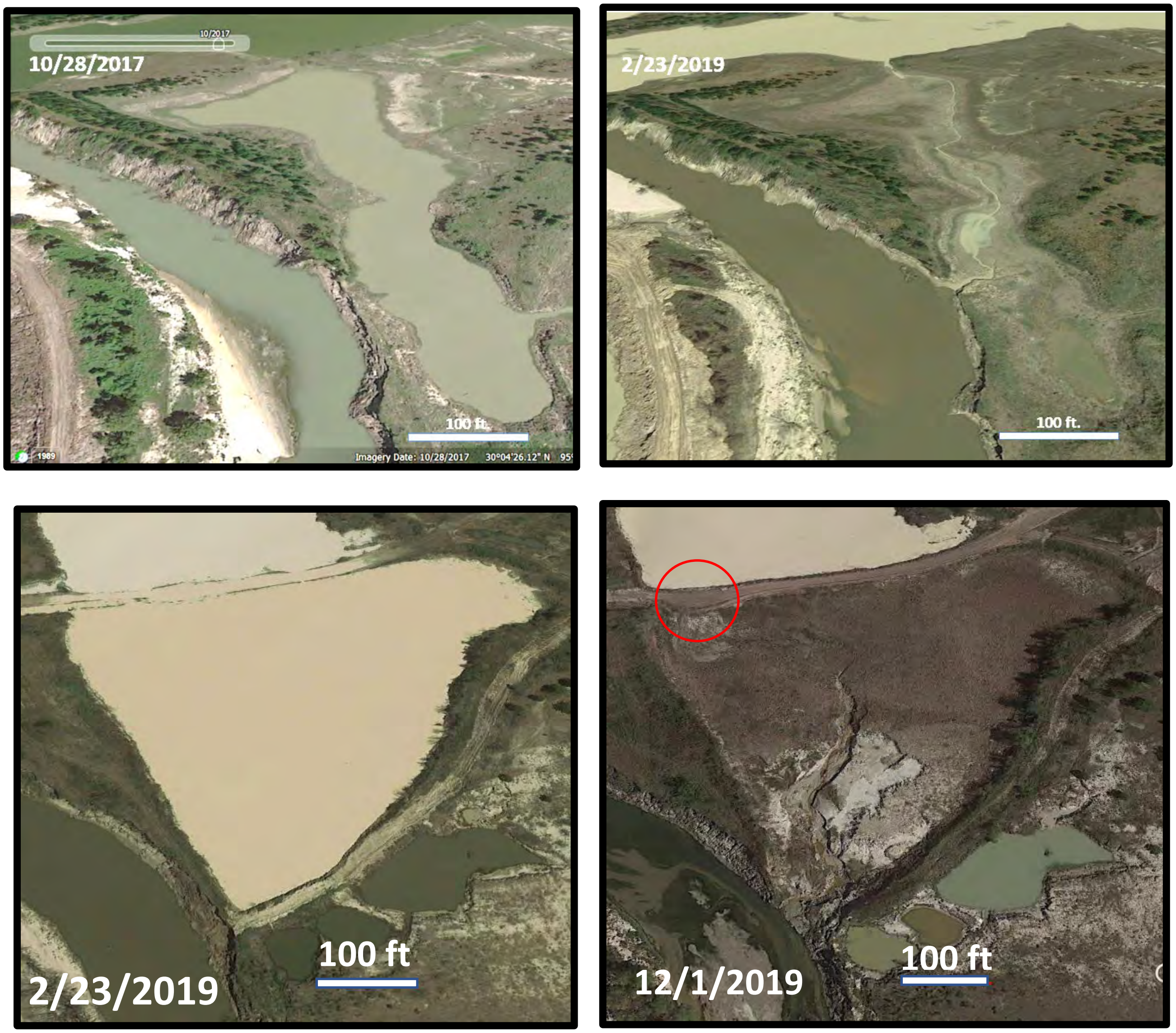

Figure 4: *Upper left*: Undrained pit on the West Fork of the San Jacinto River;
Upper right: Same pit after being drained by breach that formed on Oct. 30, 2019 ;
Lower left: Another undrained pit on the West Fork of the San Jacinto River breach;
Lower right: Same pit showing extensive erosion of exposed pit sediment when drained.
Red circle indicated filled breach that allowed process water into lower pit.

The most extreme result of breaching of levees is *"pit capture"* resulting in the re-routing of the river into and through the pits (e.g. Mossa & Marks, 2011; Ladson & Judd, 2014). Breaches are so common that Kondolf (1997) wrote "…in general, pit capture is inevitable for floodplain pits." Such events cause *major environmental impacts*, including upstream incision, erosion and bank collapse, infrastructure failure, flow stagnation, loss of habitat, sediment deposition in the pit, and downstream erosion, sediment deposition, and flooding. In some cases, river erosion or pit overtopping has resulted in pits being completely drained, resulting in extensive erosion of the pit bottom and further downstream pollution. In the examples shown in Google Earth images in figure 4, breaches formed in October, 2019, resulted in an exceptionally large unauthorized discharge of process water of approximately 56 million gallons (TECQ Investigation No.:1609552 Incident No.:324250).

In addition, increased erosion of poorly maintained or non-vegetated levees (Figure 5) can introduce increased amounts of coarse-grained sediment into the river during and after floods. When increased amounts of sandy sediment leaves the mine area, deposition of sand bars and increased flooding can locally occur downstream.

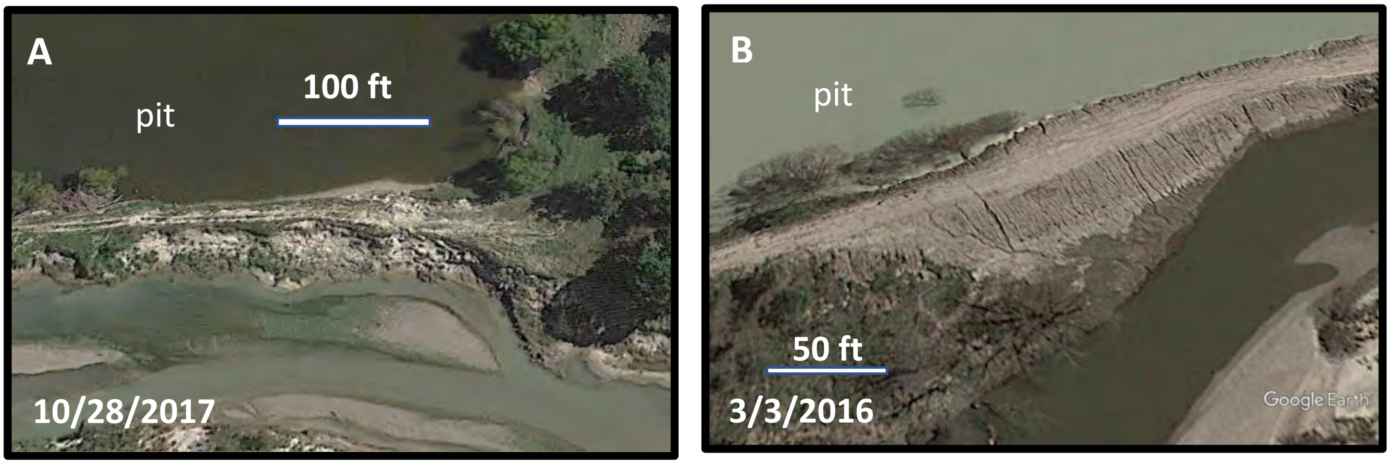

Figure 5: Erosion on non-vegetated levees between pits and West Fork of the San Jacinto River. A. Increased slumping note the increased erosion of the levee compared to the vegetated area to the right; B. gully erosion on non-vegetated levee.

Levees at sand pits in the West Fork of the San Jacinto River are often repeatedly breached by floods of varying magnitudes, and some breaches are left unrepaired for months or years (Rehak, 2018a). Unfortunately, some breaches (and man-made drains) spill into adjacent land and waterways; may be the result of improper (and illegal) actions by mine operators. Once abandoned, pits are especially prone to breaching, sediment pollution, and pit capture, because river erosion and flooding continue while levee maintenance is neglected. Such changes, in turn, can continue to cause *major changes* in the equilibrium of the river system both upstream and downstream.

In-stream mining: Since the passage of Section 404 of the Clean Water Act Amendments of 1977, some states have heavily restricted or banned in-stream mining, as have many countries. These restrictions are mainly based on the significant environmental problems associated with this type of mining *(see recent summaries by Ladson & Judd, 2014; Koehnken et al., 2020).* Major disruption of benthic and riparian habitats due to dredging and increased sediment is put into suspension. Changes in turbidity, total dissolved solids (TDS), temperature, dissolved oxygen, pH, and resuspended toxicant further impact water quality. Major channel modifications can also occur, including upstream incision (headcutting) and downstream erosion and deposition, especially where mining extends below the bottom of the channel base (thalwag). Incision can also result in lowering of water table adjacent to the stream, affecting riparian environments and bank stability. The environmental impacts of such mining are far greater than that typically associated with floodplain mines.

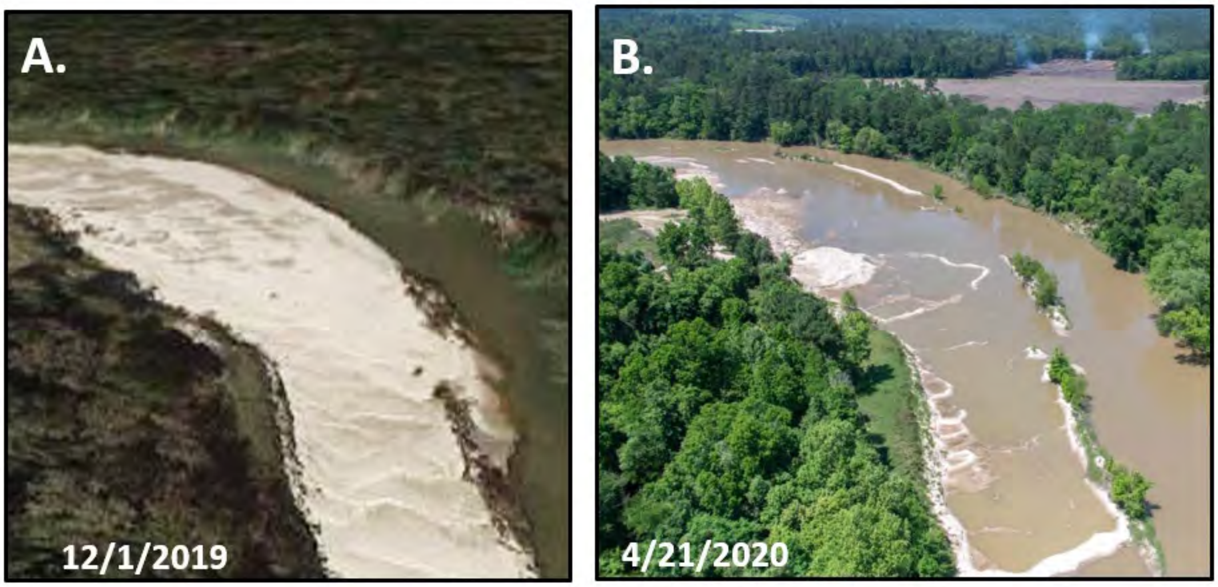

Figure 6: A. Google Earth image of point bar on the west Fork of the San Jacinto River; B. Same bar 5 months later showing un-permitted (i.e. illegal) In-stream “bar-scrapping”. Note lack of barrier between pits and channel. (photo courtesy of Robert Rehak)

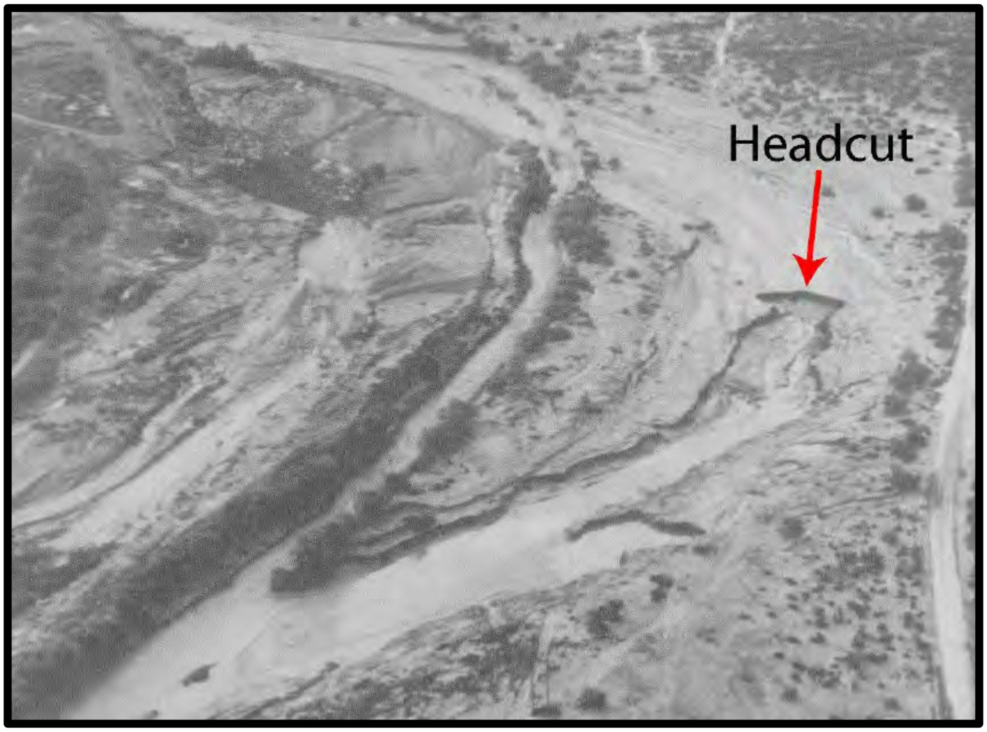

Figure 7: Upstream head-cut erosion on the Santa Cruz River floodplain caused by in-river mining (Baker et al., 1988)

III Current State Regulations:

The costs to mitigate these impacts are currently being borne by counties, insurers, and homeowners. Regulatory change is urgently needed to transfer these costs to the operations which are the root cause of the problem. Based on the input received by the Committee, TCEQ is not currently able to keep up with the development of new sand and gravel operations; permitting is inadequate, and inspection/enforcement is clearly insufficient, based on the observed impacts on river systems in the vicinity of these operations. Thus, the following discussion of the present state and local regulations is pertinent.

Statewide Regulations

The registration and inspection of APO's is the responsibility of the TCEQ under HC 571*(Texas Water Code, 2011)*, and has significantly reduced the number of unauthorized mining. It also requires, among other things, that all active sites be "inspected for compliance with applicable environmental laws and rules under the jurisdiction of the commission [TCEQ] at least once every three years."

The Texas Surface Water Quality Standards (TSWQS) sets the TDS numeric limit of 4oo mg/L for the San Jacinto River Basin as a part of the Designated Uses and Numeric Criteria

The regulation of discharges from quarry operations is the responsibility of the TCEQ under the *Multi-Sector General Permit (MSGP) TXR0500000* (*TCEQ, 2016*). This includes Stormwater Pollution Prevention Plan (SWP3) requirements, some of which include:

- Require the use of structural and/or non-structural controls to reduce soil erosion and sedimentation in areas of the facility with demonstrated or potential soil erosion and sedimentation.
- Require annual site evaluation and an overall assessment of the effectiveness of the current SWP3.
- Monitor, sample, examine, and inspect stormwater discharges within 72 hrs. of any breach resulting in unauthorized discharges; discharges must be reported to TCEQ within 24 hrs. if may endanger human health or safety, or the environment.

  Unfortunately, breaches and unauthorized discharges are sometimes left unreported and unrepaired unless citizens filed reports to the TCEQ. Even when violations have been documented by the TCEQ, fines have been minimal, averaging ~$800/violation from 2013-2017 *(from TCEQ report to Texas legislature, in: Rehak, 2018).*

Mining of marl, sand, and gravel from navigable rivers in Texas is regulated (*Texas Administrative Code, 2019*) by the Texas Department of Parks and Wildlife (TPWD), where applicants are required to, among other things;

- Provide a sedimentation impact assessment, including an evaluation of sediment budget, erosion rates of the river segment to be affected, and the effect on coastal and receiving waters, approved by the department" (RULE §69.105).

However, in-river mining has continued along the West Fork of the San Jacinto River even though no permits have been granted by TPWD, and enforcement appear to be lax (see discussion in Rehak, 2020). Thus, it is likely the regulation described above will have little or no effect in the absence of increased enforcement.

Area-specific Regulations

1. **John Graves Scenic Riverway**: There is, however, a major piece of state legislation enacted by Senate Bill 1354 during the 79th Texas Legislature (established by *Water Code, Chapter 26, Subchapter M),* which created the John Graves Scenic Riverway. This law established a pilot program to enhance water quality protection by establishing specific regulations for quarries within the watershed. This program could serve as a template for BMP's the SJRW. The specific requirements of the legislation (TCEQ, 2008) are as follows:

   - Require interagency coordination of inspections and sampling within the John Graves Scenic Riverway.

- Quarries located in a designated water quality protection area more than one mile from a water body must obtain a general permit.

- Quarries within one mile of a water body, or within the 100-year floodplain of a water body, must obtain an individual permit.

- New quarry operations or the expansion of existing operations between 200 feet and 1,500 feet of a water body are prohibited, unless an applicant for an individual permit can demonstrate, and the TCEQ can substantiate, that certain specific requirements are satisfied. These include specific performance criteria established by the TCEQ; plans for control of erosion and protection of fish and wildlife habitat and public and private property; plans for reclamation of a quarry; and the use of best available technology.

- Unless otherwise exempted by the legislation, new quarry operations or the expansion of existing operations are prohibited within 200 feet of a water body within a water quality protection area designated by the TCEQ;

- Any permit issued under SB 1354, … shall satisfy effluent limits established by the TCEQ, meet requirements for financial assurance, and include a plan for restoration of receiving waters in the event of an unauthorized discharge."

2. **County Floodplain Management Regulations:** As part of the Flood Control Insurance Act, *Texas Water Code, Section 16.315* delegated responsibility to local governmental units (typically counties), allowing them to adopt regulations designed to minimize flood losses. Given that all the mines in the San Jacinto River Watershed are located either partially or entirely in the *regulated floodway*, industry-wide compliance with locally developed rules could result in significantly reduced flooding, and flood-related erosion/sedimentation. For example, the following is an excerpt from the Montgomery County Flood Plain Management Regulations (2014).

   "Section E. Floodways: Located within special flood hazard areas established in Article III, Section B, are areas designated as floodways. Since the floodway is an extremely hazardous area due to the velocity of flood waters which carry debris, potential projectiles and erosion potential, the following provisions shall apply:

   (1) Encroachments are prohibited, including but not limited to fill, new construction, substantial improvements and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge. A development permit must be secured from the Flood Plain Administrator prior to the placement of fill or other encroachment in the floodway."

IV. Recommendations:

APO's clearly must follow existing Federal, State, and local regulations, some of which are discussed above. In some cases, this will require increased monitoring (and funding?) on the part of the regulating agencies. However, compliance with existing regulations will be made more efficient with the adoption of *Best Management Practices* (BMP's) for APO's**.** BMP's established to address the myriad issues regarding APOs need to include provisions which apply specifically to quarry operations occurring *on or near specified riverways and their associated floodplains,* because these operations differ significantly from APO's located elsewhere. Provisions similar to those listed above for the John Graves Scenic Riverway, as well as in many other regions (e.g. Louisiana Dept. Environmental Quality, 2007; Alaska Dept. Environmental Conservation, 2012; Alberta Sustainable Resource Development, 2010), should be included in any BMP's related to quarries along specified riverways and their associated floodplains. Specific recommendation could include:

- All APO's should develop and make available to regulators and the public a *Comprehensive Mine Plan* and an Environmental Assessment Report on potential impacts associated with the planned development before permits are issued. The Mine Plan should include a comprehensive evaluation of site pre-existing conditions (i.e. baseline data on surface and groundwater quality, flood and erosion risk existing ecosystems, wetlands, underground facilities, etc.). For floodplain mines there should be specific studies as to existing conditions (e.g. water quality, riparian and benthic habitats, flood and erosion potential), and potential environmental impacts at the site and upstream and downstream (e.g. potential bridge or pipeline failure).

- All APO's should develop and make available to regulators and the public a *Reclamation Plan* before permits are issued. and to file a *performance bond* ensuring reclamation of abandoned operations *before* a production permit is granted. Such permits should have significant civil and criminal *penalties for non-compliance*.

- New mining should be minimized or restricted in delineated *floodplains*, *floodways* (areas of most frequent flooding) and *channel migration zones* (areas most like to be eroded by lateral migration and river avulsion).

- Mines should be "prohibited within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses that the proposed encroachment would not result in any increase in flood levels…. A development permit must be secured from the Flood Plain Administrator prior to the placement of fill or other encroachment in the floodway…." (Montgomery County Flood Plain Management Regulations, 2014).

- Stockpiles should be located outside the floodway, because of the high potential for erosion (and resultant sediment pollution) during frequent flooding.

- Erosion control requirements should be implemented during construction, active mining, and post-mining phases to minimize damage to stream banks and riparian vegetation. Sand/gravel extraction in vegetated riparian areas should be avoided. Undercut and incised vegetated banks should not be altered. Large woody debris in the riparian zone should be left undisturbed or replaced when moved and not be burnt. Only clear and grub acreage as needed for the immediate term.

- A natural [vegetated] riparian buffer should be maintained along the margins of streams to both resist erosion and shade and cool the river.

- A minimum buffer zone width should be maintained between pits and perennial and ephemeral streams, adjacent landowner's properties, and public water supply and domestic water wells. Such buffer widths should also take into account documented rates of river erosion.

- Minimum widths and slopes for protective levees should be required to avoid breaches allowing water to enter or exit the pits. If located in the 100-yr. (1%) floodplain, levees should be designed to withstand flooding and erosion from a 100-yr. (1%) flood. Levees should not restrict the stream flow during a major flood as that can cause increased flooding.

- Mining below the depth of the adjacent channel bottom (thalwag) should be restricted or prohibited in order to minimize potential for pit capture.

- There should be regularly water-quality sampling (e.g. sediment/turbidity, hydrocarbons, chlorides, sulfates, TDS (total dissolved solids), pH, DO [dissolved oxygen], cyanobacteria, and other likely contaminants) from surface sampling during the active mining phase by the operators and the results reported to the appropriate agencies (c.f. that required for John Graves Scenic Riverway – SB 1354). Aerial surveillance and surface sampling by regulating agencies may also be needed.

- Post-mining reclamation should return the site to a sustainable natural or economically usable state, in consultation with the landowner. This should include (but not be limited to) removal of waste piles and equipment, regrading of pit areas, repair of damaged stream banks, stabilization of pit slopes, streambanks, and levees, revegetation pit areas and levees, and measures to limit access to abandoned pits. Levee design and maintenance must be adequate to avoid pit capture during future floods. Establish drainage patterns that re-establish stream flows downstream of the mining property and minimize potential for erosion and flooding.

VI. Summary:

Aggregate mining clearly provided valuable material and employment to the state and nation. Nonetheless, Texas is one of the few states where sand and gravel mines (and other types of APO's) remain largely unregulated. Issues related to flooding, erosion, and sedimentation are but a few of the many unintended (and undesirable) environmental and economic impacts associated with sand and gravel mines in Texas, and especially in the SJRW. Based on extensive reports in the literature and expert testimonies provided to this hearing and elsewhere, I believe there is a clear need for the requirement fort BMP's to better protect the public and the environment.

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Appendix A – Selected Floodplain Mining Impacts and Risks

Selections from: Jacobs and Moroka. (2015). Review of floodplain mining impacts and risks: Final Report prepared by Jacobs and Moroka for Goulburn Broken Catchment Management Authority.

Elements of Avulsion	Nature of Impact		
	Upstream	Local	Downstream
Geomorphic characteristics	• Incision of channel • Increased gradient • Coarsening of bed • Undercutting and erosion of banks ▯ +/- lateral migration rates	• Alluvial fan development • Reshaping of pits • Loss of natural channel geometry • Increased open water area	• Increased lateral migration • Increased channel width • Incision
Sediment transport	• Increased sediment transport capacity • Reduction in bed load deposition	• Deposition of sediment in pits • Short-term increase in turbidity • Erosion of gravel pit banks	• Reduced sediment supply • Erosion of bed • Coarsening of bed • Increased bank erosion • Short term increase in fine sediment supply
Hydraulics	• Increased slope • Increased velocities • Decreased normal depth • Increased bed roughness	• Decreased slope • Increased channel depth • Increased channel width • Reduced bed roughness	• Increased bed roughness
Hydrology		• Increased flood storage • Increased evaporation • Altered groundwater flow patterns	• Reduction of flood levels • Attenuation of flood peaks • Changes in summer low flows • Lower riparian groundwater levels due to bed lowering
Water Quality		• Temperature increase • Short-term increase in turbidity • Alteration of hyporheic zone	• Temperature increase • Short-term increase in turbidity

Aquatic Habitat	• Habitat disruption or loss due to channel incision • Potential conversion of habitat type/quality Short- and long-term habitat instability	• Conversion of free-flowing habitat to still water habitat • Potential capture of fish following floods • Potential release of non-native species from captured pits • Alteration of hyporheic zone • Short- and long-term habitat instability	• Habitat disruption or loss due to erosion of bed • Habitat loss due to altered sediment supply • Potential conversion habitat type/quality • Short- and long-term habitat instability

Table 2.1: Summary of potential impacts caused by floodplain pit capture (after Bureau of Reclamation 2005) in: (Jacobs & Moroka, 2015).

River	Physical Impacts	Infrastructure Impacts	Reference
Goulburn Valley, Victoria	Capture of Island Creek tributary (piping failure of bank) caused a knickpoint to progress upstream 340 m, substantial bank collapse and widening, toppled multiple mature red gums.	Destroyed a road crossing	Craigie (2012)
Georges River, NSW	Many gravel pits have been captured by the river, increasing tidal velocities and causing channel erosion.		Warner and Mclean (1977)
Tangipahoa River, Louisiana	Six gravel mining pits located within 150 m of the channel, up to 15 m deep were captured by the river between 1980 and 2004. Up to 6 m of bed degradation occurred upstream of pit captures, with aggradation downstream.	highway bridge failed because of the bed degradation	Mossa and Marks (2011)
Big Escambia Creek, Florida	Avulsion through several pits shortened the length and shifted the creeks junction with the Ecambia River 1.2 km upstream.	Damages led to a $7.7 million (USD) stream restoration project.	U.S. Army Corps of Engineers Mobile District (2000)
Rogue River, Oregon	Floods progressively eroded the bank and flow entered the pit.	Bank erosion progressed upstream onto a residential property and downstream to a powerline which was lost.	Klingman (1998)
Clackamas River, Oregon	High flows led to the capture of an off-channel pit and resulted in 2 m of incision that extended 1 km upstream .	Incision and bank erosion caused undermining of a building at the gravel mine site.	Kondolf (1997)

Table 2.2: Documented physical and infrastructure impacts resulting from river channel changes caused by floodplain mining (Jacobs & Moroka, 2015).

Likelihood		Lateral migration of river channel into the pit	Sub-surface piping into pit and subsequent failure of pit walls	Flow of floodwater into and through the pit and subsequent erosion of the buffer strip between the channel and the excavated pit
1	*Rare*	*80-100 m bank erosion over 100 years*	*80-100 m from edge of waterway*	*Basement of pit more than 5 m higher than invert of river**
2	*Unlikely*	*60-80 m bank erosion over 100 years*	*60-80 m from edge of waterway*	*Basement of pit 1-5 m higher than invert of river*
3	*Moderate*	*40-60 m bank erosion over 100 years*	*40-60 m from edge of waterway*	*Basement of pit at same elevation as invert of river*
4	*Likely*	*20-40 m bank erosion over 100 years*	*20-40 m from edge of waterway*	*Basement of pit 1-5 m lower than invert of river*
5	*Almost certain*	*10-20 m bank erosion over 100 years*	*10-20 m from edge of waterway*	*Basement of pit more than 5 m lower than invert of river*

Table 2.6: Likelihood criteria to assess pit capture for each risk scenario (Jacobs & Moroka, 2015).

*Invert of the river = base of the channel (thalwag)

Appendix B – Sand and Gravel Mining Policies

Selections from: Pinal County Department of Public Works - Sand and Gravel Mining Floodplain Use Permit – 2006

Sand and Gravel Mining Policies

Aggregate mines should be located outside of the REGULATORY FLOODWAY whenever feasible.

Aggregate mines should be located outside of the erosion hazard zone whenever feasible.

If aggregate mines are located within the regulatory floodway or erosion hazard zone and no STRUCTURAL FLOOD CONTROL MEASURES are provided, the maximum excavation depth should be no greater than the natural CHANNEL INVERT elevation shown on the EFFECTIVE FLOODPLAIN DELINEATION study (Figure 5-1).

If aggregate mines within the floodplain or erosion hazard zone are excavated below the natural channel invert elevation shown on the effective floodplain delineation study, then engineered GRADE CONTROL STRUCTURES should be provided at any point where the 100-year flood could enter the excavation, or ENGINEERED FLOOD CONTROL STRUCTURES shall be provided to prevent the 100-year flood from entering the excavation.

Aggregate mines shall have no adverse floodplain, EROSION, or sedimentation impacts on any adjacent or off-site property.

Aggregate mining operations must have a RECLAMATION plan that assures the long-term stability of the excavation and the adjacent river system.

Aggregate mining operations shall be compatible with the recommendations and policies specified in the approved watercourse master plan for that watercourse, if one exists, or the applicable area drainage master plan for the watershed.

Technical reports submitted in support of aggregate mining floodplain use permits should be prepared by experienced Arizona-registered professional engineers with relevant expertise in hydrology, hydraulics, sediment transport, river mechanics, FLUVIAL GEOMORPHOLOGY, and local stream systems.

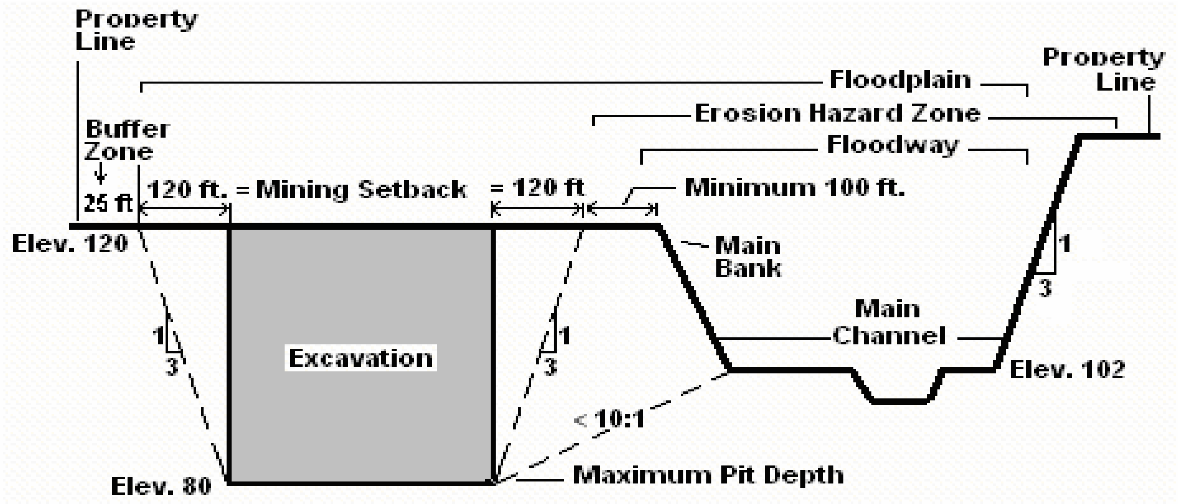

Figure 5-3. Floodplain excavation pit geometry for streamlined floodplain use permit. Pit is 40 ft deep. (Pinal Co Arizona)

6.7 Statement of Findings

6.7.1 Floodplain standards have been satisfied
    a. FEMA
    b. Local
6.7.2 Floodway standards have been satisfied
    a. FEMA
    b. Local
6.7.3 No offsite impacts will occur
    a. Upstream
    b. Downstream
    c. Tributaries
    d. Local drainage
    e. Structures
    f. Groundwater
    g. Stream form and function
6.7.4 Need for structural flood control has been addressed
    a. Vertical scour and degradation
    b. Lateral erosion
6.7.5 A reclamation plan is provided
6.7.6 Compliance with regulations and guidelines
    a. FEMA Regulations
    b. All State and Federal agency permits will be obtained prior to mining

Table 2-3: Physical effects of sand and gravel mining in rivers

- Extraction of bed material in excess of replenishment by transport from upstream causes the bed to lower (degrade) upstream and downstream of the site of removal.

- Bed degradation can undermine bridge supports, pipe lines or other structures.

- Degradation may change the morphology of the river bed, which constitutes one aspect of the aquatic habitat.

- Degradation can deplete the entire depth of gravelly bed material, exposing other substrates that may underlie the gravel, which could in turn affect the quality of aquatic habitat.

- If a floodplain aquifer drains to the stream, groundwater levels can be lowered as a result of bed degradation.

- Lowering of the water table can destroy riparian vegetation.

- Flooding is reduced as bed elevations and flood heights decrease, reducing hazard for human occupancy of floodplains and the possibility of damage to engineering works.

- The supply of overbank sediments to floodplains is reduced as flood heights decrease.

- Rapid bed degradation may induce bank collapse and erosion by increasing the heights of banks.

- In rivers in which sediments are accumulating on the bed (aggrading) in undisturbed condition, gravel extraction can slow or stop aggradation, thereby maintaining the channel's capacity to convey flood waters.

- The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilise, depending on the amount of sand and gravel removed, the distribution of removal, and on the geometry of the particular bend.

- Removal of gravel from bars may cause downstream bars to erode if they subsequently receive less bed material than is carried downstream from them by fluvial transport.

Source: Collins and Dunne (1990). Fluvial Geomorphology and River-Gravel Mining: A Guide for Planners, Case Studies Included. Special Publication 98, California Department of Conservation, Division of Mines and Geology.

Appendix C - Overview of in-stream sand and gravel mining

Selections from: Langer, W.H. (2003), A General Overview of the Technology of In-Stream Mining of Sand and Gravel Resources, Associated Potential Environmental Impacts, and Methods to Control Potential Impacts: U.S. Geological Survey Open-File Report 02-0153, 44 p.

Impacts [for in-stream mining] may, but do not necessarily, include:

- Channel modifications such as widening or deepening the channel, creation of deep pools, loss of riffles, alteration of bedload, alteration of channel flow, and degraded aesthetics.
- Upstream and downstream erosion and related impacts.
- Modifications of aquatic habitat including spawning beds, nursery habitat, shellfish habitat, and riparian habitat.
- Degradation of water quality including increased turbidity, reduced light penetration, increased temperature, and resuspension of organic or toxic materials.
- Bridge scour and other impacts to infrastructure.

The impacts from stream avulsion and pit capture can be avoided by constructing a controlled spillway in a levee along the stream … The levee is designed with armored spillways that control where the levee will be "breached" by the stream during flooding. The spillway allows water to leave the channel and temporarily flow over the floodplain but keeps stream from creating a new channel and keeps the bedload in the stream.

… the impacts of improper in-stream aggregate mining on aquatic habitat. Erosion caused by in-stream mining can cause bank failure, which can cause loss of riparian habitat and loss of shade along streambanks. Channel shortening can increase flow rates, which can reduce the occurrence of coarse woody debris in the channel. In-stream mining can result in channel bed armoring, destabilization of spawning gravels and nursery habitat, increases in suspended sediment load, lowering of alluvial water tables, and stagnant low flows…

Turbidity can be controlled by containing runoff and by filtering or containing wash water….

Some researchers believe that environmental impacts from in-stream mining can be avoided if the annual bedload is calculated and aggregate extraction is restricted to that value or some portion of it….

Extracting sand and gravel from floodplains generally is preferable to removing sand and gravel from stream channels. Extracting sand and gravel from terraces is generally preferable to extracting sand and gravel from floodplains. In-stream extraction of gravel from below the water level of a stream generally causes more changes to the natural hydrologic processes than limiting extraction to a reference point above the water level.

- In-stream extraction of gravel below the deepest part of the channel (the thalweg) generally causes more changes to the natural hydrologic processes than limiting extraction to a reference point above the thalweg.

There are some general operating practices that can be followed to limit environmental impacts from in-stream mining. They are:

- Extracting sand and gravel from areas of riffles commonly should be avoided because removing gravel from riffles commonly results in increased erosion and threatens important fish habitat.
- Relocating or straightening stream channels commonly should be avoided because such actions shorten the stream, which results in increased stream velocity and associated erosion.
- Settling ponds for sand and gravel wash water should properly sized, should be protected so that they are not inundated during flooding, and should be located far away from the channel so that the warm, silty wash water cannot enter the stream.
- Berms, dikes, and stockpiles can modify flood levels and flow patterns. Berms and dikes should be designed with this in mind, and stockpiles should be located out of the floodplain or as far away from the channel as possible.
- An undisturbed buffer should be maintained at the top of the bank for the length of the excavation, and the access areas should be replanted once excavation is completed.
- Mining should be avoided during spawning seasons or other critical habitat times if sand and gravel extraction cause increased turbidity.
- Clearing of riparian woodlands should be avoided when sufficient material can be obtained in less densely vegetated areas.
- Waterlogged trees, deadheads, and large boulders can be placed along streamside to provide diversity of habitat.
- Aggregate extraction can add to habitat diversity by varying configuration, slopes, and elevations of graded areas during final reclamation.

Human reclamation of river or stream environments requires a design plan and product that responds to a site’s physiography, ecology, function, artistic form, and public perception (Arbogast and others, 2000).

8. The principal cause of impacts from in-stream mining is the removal of more bedload than the system can replenish or the shortening of the stream channel. A decrease in bedload or channel shortening can cause head-cutting and downstream erosion. The stream may change its course, thus causing bank erosion and the undercutting of structures. In-stream mining can also result in creation of deep pools, loss of riffles, channel shortening, over-widening channels, increased turbidity, and changes in aesthetics. All these impacts can result in major changes to aquatic and riparian habitat, and associated impacts to the biota occupying those habitats.

Appendix D – Sustainable sand mining guidelines

Selections from: Singh, S.M.K., Sridharan, U., Lai, R.B., and Singh, S., 2016, Sustainable Sand Mining Management Guidelines, Ministry of Environment, Forest and Climate Change, Government of India, 98 p.

The effects of sand and gravel mining are as follows:

a) Extraction of bed material in excess of replenishment by transport from upstream causes the bed to lower (degrade) upstream and downstream of the site of removal.

b) In-stream habitat is impacted by increase in river gradient, suspended load, sediment transport and sediment deposition. Excessive sediment deposition for replenishment increases turbidity which prevents penetration of light required for photosynthesis and reduces food availability of aquatic fauna

c) Riparian habitat including vegetative cover on and adjacent to the riverbanks it controls erosion, provide nutrient inputs into the stream and prevents intrusion of pollutants in the stream through runoff. Bank erosion and change of morphology of the river can destroy the riparian vegetative cover.

d) Bed degradation are responsible for channel shifting, causing loss of properties and degradation
of landscape, it can also undermine bridge supports, pip lines or other structures.

e) Degradation may change the morphology of the riverbed, which constitutes one aspect of the aquatic habitat.

f) Degradation can deplete the entire depth of gravelly bed material, exposing other substrates that may underlie the gravel, which could in turn affect the quality of aquatic habitat. Lowering of ground water table in the flood plain because of lowering of riverbed level as well as river water level takes place because of extraction and draining out of excessive ground water from the adjacent areas. So, if a floodplain aquifer drains to the stream, groundwater levels can be lowered as a result of bed degradation.

g) Lowering of the water table can destroy riparian vegetation.

h) Excessive pumping of ground water in the process of mining in abandoned channels depletes ground water causing scarcity of irrigation and drinking water. In extreme cases it may create ground fissures and subsidence in adjacent areas.

i) Flooding is reduced as bed elevations and flood heights decrease, reducing hazard for human occupancy of floodplains and the possibility of damage to engineering works.

j) The supply of overbank sediments to floodplains is reduced as flood heights decrease.

k) An un-scientific and unregulated sand and gravel mining tends to increase channel bank scouring and erosion. This causes a large degree of meandering of rivers and sometimes it could be in kms.

l) Rapid bed degradation may induce bank collapse and erosion by increasing the heights of banks.

m) Polluting ground water by reducing the thickness of the filter material especially if mining is taking place at top of recharge fissures.

n) Choking of sand layer which acts as filter for ingress of ground water from river by dumping of finer material, compaction of filter zone due to movement of heavy vehicles. It also reduces the permeability and porosity of the filter material.

o) Removal of gravel from bars may cause downstream bars to erode if they subsequently receive less bed material than is carried downstream from them by fluvial transport.
p) Ecological effects on bird nesting, fish migration, angling, etc.
q) Indiscrete mining activities lead to increased concentration of suspended sediment in the river which in turn causes siltation of water resources projects.
r) Un-scientific and unregulated sand and gravel mining leads to the severe health hazards like air quality degradation and dust fog.
s) Direct destruction from heavy equipment operation; discharges from equipment and refueling.
t) Biosecurity and pest risks.
u) Impacts on coastal processes

The other deleterious impacts of indiscrete mining include
Loss of riparian habitat resulting from direct removal of vegetation along the stream bank to facilitate the use of a dragline or through the process of lowering the water table, bank undercutting, and channel incision. The physical composition and stability of substrates are altered as a result of instream mining and most of these physical effects may exacerbate sediment entrainment in the channel.

Furthermore, the process of in-stream mining and gravel washing produces fine sediments under all flow conditions, resulting in a deposition of fine sediment in riffles as well as other habitats at low discharge. Excess sediment is considered the greatest pollutant in waters and constitutes one of the major environmental factors in the degradation of stream fisheries.

4. Reclamation Plans

Reclamation plans should include:
a) A baseline survey consisting of existing condition cross-section data: Cross-sections must be surveyed between two documented endpoints set back from the top of bank, and elevations should be referenced to benchmark;
b) The proposed mining cross-section data should be plotted over the baseline data to illustrate the vertical extent of the proposed excavation;
c) The cross-section of the replenished bar should be the same as the baseline data. This illustrates that the bar elevation after the bar is replenished will be the same as the bar before extraction;
d) A planimetric map showing the aerial extent of the excavation and extent of the riparian buffers;
e) A planting plan developed by a plant ecologist familiar with the flora of the river for any areas such as roads that need to be restored;
f) A monitoring plan: The appropriate reclamation plans can turn river-bed and floodplain sand and gravel mining operations into something perceived by the public as desirable.

Appendix E – River sand mining guidelines

Selections from: Department of Irrigation and Drainage. (2009). River Sand Mining Management Guidelines Malaysia: Ministry of Natural Resources and Environment, Department of Irrigation and Drainage, Malaysia.

Collins et al. (1990) summarized the effects of sand and gravel mining as listed below:

a) Extraction of bed material in excess of replenishment by transport from upstream causes the bed to lower (degrade) upstream and downstream of the site of removal.
b) Bed degradation can undermine bridge supports, pipelines or other structures.
c) Degradation may change the morphology of the riverbed, which constitutes one aspect of the aquatic habitat.
d) Degradation can deplete the entire depth of gravelly bed material, exposing other substrates that may underlie the gravel, which could in turn affect the quality of aquatic habitat.
e) If a floodplain aquifer drains to the stream, groundwater levels can be lowered as a result of bed degradation.
f) Lowering of the water table can destroy riparian vegetation.
g) Flooding is reduced as bed elevations and flood heights decrease, reducing hazard for human occupancy of floodplains and the possibility of damage to engineering works.
h) The supply of overbank sediments to floodplains is reduced as flood heights decrease
i) Rapid bed degradation may induce bank collapse and erosion by increasing the heights of banks.
j) In rivers in which sediments are accumulating on the bed (aggrading) in undisturbed condition, gravel extraction can slow or stop aggradation, thereby maintaining the channel's capacity to convey flood waters.
k) The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilize, depending on the amount of sand and gravel removed, the distribution of removal, and on the geometry of the particular bend.
l) Removal of gravel from bars may cause downstream bars to erode if they subsequently receive less bed material than is carried downstream from them by fluvial transport.

3.1.1 In-Stream Mining Recommendations

a) Permit Mining Volume Based on Measured Annual Replenishment
b) Establish an Absolute Elevation below Which No Extraction May Occur (Minimum Enveloped Level or Redline)
c) Limit In-stream Extraction Methods to Bar Skimming
d) Extract Sand and Gravel from the Downstream Portion of the Bar
e) Concentrate Activities to Minimise Disturbance
f) Review Cumulative Effects of Sand and Gravel Extraction
g) Maintain Flood Capacity
h) Establish a Long-term Monitoring Program
i) Minimise Activities That Release Fine Sediment to the River
j) Retain Vegetation Buffer at Edge of Water and Against River Bank
k) Limit In-stream Operations to the Period Between May and September

l) An Annual Status and Trends Report

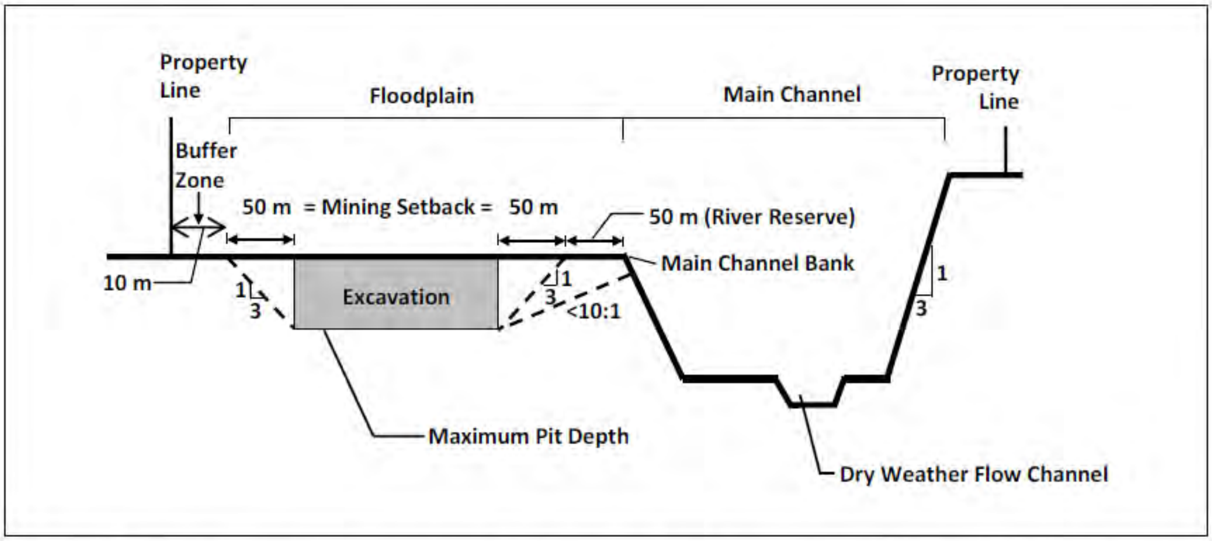

Figure 1.3: Floodplain Excavation Pit Geometry for Streamlined Floodplain Use Permit

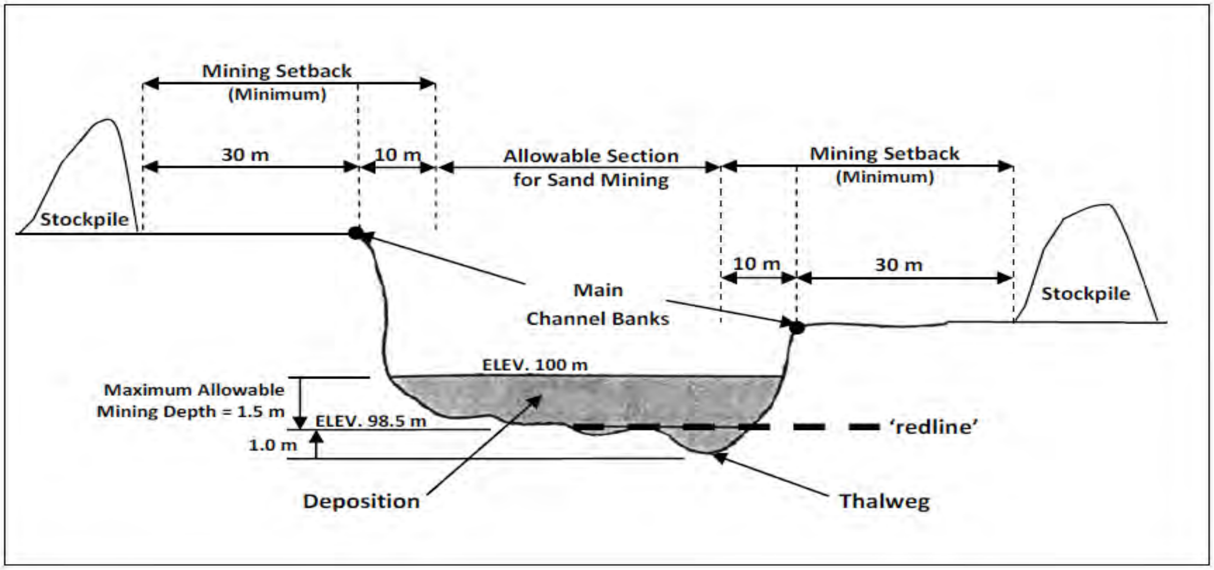

Figure 1.2: Setback, "redline" and Maximum Allowable Mining Depth for In-Stream Mining

3.1.2 Off-Channel or Floodplain Extraction Recommendations

a) Floodplain Extraction Should Be Set Back from the Main Channel
b) The Maximum Depth of Floodplain Extraction Should Remain above the Channel Thalweg
c) Side Slopes of Floodplain Excavation Should Range from 3:1 to 10:1
d) Place Stockpiled Topsoil above the 25-year Return Period or ARI Level
e) Floodplain Pits Should Be Restored to Wetland Habitat or Reclaimed for Agriculture
f) Establish a Long-term Monitoring Program
g) An Annual Status and Trends Report

3.1.3 Reclamation Plans

In-stream reclamation plans should include:

a) a baseline survey consisting of existing condition cross-section data. Cross-sections must be surveyed between two monumented endpoints set back from the top of bank, and elevations should be referenced to JUPEM's bench mark;
b) the proposed mining cross-section data should be plotted over the baseline data to illustrate the vertical extent of the proposed excavation;
c) the cross-section of the replenished bar should be the same as the baseline data. This illustrates that the bar elevation after the bar is replenished will be the same as the bar before extraction;
d) a planimetric map showing the aerial extent of the excavation and extent of the riparian buffers;
e) a planting plan developed by a plant ecologist familiar with the flora of the river for any areas such as roads that need to be restored;
f) a monitoring plan (See Chapter 4).

The potential impacts of gravel extraction are well known from literature (e.g., Kelly et al. 2005; Rinaldi et al. 2005) and include:

a) bed degradation and consequent effects on channel and bank stability (Figure 2.12);
b) increased sediment loads, decreased water clarity and sedimentation;
c) changes in channel morphology and disturbance of ecologically important roughness elements in the river bed;
d) ecological effects on bird nesting, fish migration, angling, etc.
e) modification of the riparian zone including bank erosion;
f) direct destruction from heavy equipment operation;
g) discharges from equipment and refuelling;
h) Reduction in groundwater elevations;
i) impacts on structures and access;
j) biosecurity and pest risks;
k) impacts on coastal processes.

Appendix F – Effects of floodplain gravel mining

Selections from: Ladson, A. R. & Judd, D. A. (2014). A review of the effect of floodplain gravel on river stability, in Vietz, G; Rutherfurd, I.D, and Hughes, R. (editors), Proceedings of the 7th Australian Stream Management Conference. Townsville, Queensland, Pages 249-259.

Immediate implications of floodplain gravel mining

During gravel mining, the immediate area of the mine will be affected by impacts that include:

- Loss of agricultural land
- Loss of riparian vegetation and riparian habitat
- Loss of floodplain habitat
- Increases in noise and dust
- Disturbance of heritage values
- Disturbance of cultural values
- Potential concern related to impacts on rare and threatened species
- Changes in aesthetics, particularly a change in scenic quality.

Delayed impacts of floodplain gravel mining

The delayed impacts of floodplain gravel mining are more severe and are generally not well regulated. These impacts include:

- The low resistance flow high flow conveyance path provided by the open area of a gravel mine can alter floodplain hydraulics during high flows
- Stockpiles of overburden and gravel on the floodplain may divert or change flow paths under flood conditions and may lead to water quality issues and downstream sedimentation (Follman, 1980)
- Mining on floodplains may reduce groundwater levels on adjacent areas where water is removed by pumping and may affect groundwater quality (Hatva, 1994; Langer, 1999)
- Floodplain mines may lead to river channel changes that include erosion, bed degradation and damage to infrastructure.

Floodplain hydraulics

Gravel mining affects flood hydraulics. Gravel pits are often leveed to restrict entry of floodwaters which will reduce floodplain storage and the area of the floodplain available for flow. This may increase flood levels and velocities in other areas of the floodplain. If floodwaters impinge on stockpiles, material, particularly fines, may be dispersed leading to sedimentation and water quality issues.

… Local turbulent flow around obstructions such as trees on the bank of extraction pits could also initiate knickpoints that develop into avulsions (Gibling et al., 1998; Tooth and Nanson, 1999). Pits can also initiate avulsions through other failure mechanisms:

- lateral migration of the river channel into the pit
- sub-surface piping from surface water into pits and subsequent failure of pit walls
- water cascading into a gravel pit as flood waters rise
- erosion by water returning to the river from the pit as the flood recedes.

Risks to river stability: case studies:

- Floodplain gravel mining on the floodplain of the Goulburn River, Victoria led to the capture of a tributary, Island Creek. This caused a knickpoint to progress upstream which undermined and toppled mature red gum vegetation and destroyed a road crossing (Figures 1, 2 and 3) (Craigie, 2012).
- On the Georges River, near Chipping Norton in western Sydney and at Lake Moore (upstream from Chipping Norton), many gravel pits have been captured by the river, increasing tidal velocities and causing channel erosion (Warner et al., 1977).
- The Fish River, near Bathurst, changed course to flow through gravel pits, as did the Nepean River at Castlereagh (Erskine, 1990).
- On the Tangipahoa River in Louisiana, six gravel mining pits (of a total of 56) were captured by the river between 1980 and 2004. Up to 6 m of bed degradation occurred upstream of pit captures, with aggregation downstream because of increased erosion. A highway bridge failed because of the bed degradation (Mossa and Marks, 2011).

- In Southern California, bed degradation of 4 m was caused when floodwaters entered a gravel pit 15 m to 23 m deep on a formerly inactive branch of the Tujunga Wash. Three bridges and seven houses were destroyed (Scott, 1973; Bull and Scott, 1974).
- Floodplain and in-channel mining on the San Benito River in California, led to 3 m of bed degradation, channel widening, loss of one bridge and damage to two others. City water and sewer mains required replacement (Harvey and Smith, 1998).
- The change in alignment caused when the Stony Creek (California, USA) broke into a gravel pit, caused local scour around the bridge piers of Interstate Highway 5, necessitating repair (Kondolf and Swanson, 1993).
- In northern Alaska, 12 of 25 floodplain gravel pits studied by the US Department of the Interior had resulted in flow diversion, or the high potential for diversion, through the pits (Rundquist, 1980, p95).
- A review by Norman et al. (1998) found that in the 14 years between 1984 and 1998, 11 floodplain gravel pits in Washington State had captured river flow. One example is the Cowlitz River where flow into a gravel pit led to a river avulsion.
- On the Clackamas River at Clackamas, Oregon, an avulsion into a gravel pit caused river bed degradation of 2 m, 500 m upstream of the pit (Kondolf et al., 1996).

- The Rogue River, Oregon, changed course into a gravel pit which resulted in erosion and loss of a tower for a power line across the river (Klingeman, 1998).
- In their review of aggregate mines on the Lower Merced River (California, USA), Kondolf et al (1996) found that the river had diverted through 8 gravel mines that were excavated on the floodplain or point bars.
- The Yakima River (Washington, USA) shifted course to flow through gravel pits near Yakima and threatened an interstate highway (Dunne and Leopold, 1978).
- Floodplain gravel mining on the Jarama River in Spain has caused the river to straighten because of diversion of the river through gravel pits (Uribelarrea et al., 2003).

- On the South Platte River in Colorado, 1.2 m of bed incision was caused between 1983 and 1986 by in-stream mining and the capture of a floodplain mining pit (Stevens et al., 1990).
- Pit capture on Blackwood Creek CA, lead to upstream and downstream bed incision and an increase in sediment delivery to a downstream lake (Todd, 1989).
- On the Amite River in Louisiana, Mossa and McLean (1997) showed a statistical link between floodplain mining and channel change.

The risk of stream diversion through pits is increased by:

- Proximity to the river (Mossa and Marks, 2011)
- Increased depth of the gravel pit, particularly where the base of the pit is below the lowest bed elevation of the deepest pools in the river.

The larger the captured pit, the greater is the change in the river (Mossa and Marks, 2011).

Norman et al. (1998) state that in the long term, stream capture by gravel pits is a near certainty. If a stream changes course to flow through a gravel mine, impacts may be similar to those of in-channel mines which include:

- Lowering the river bed level by erosion upstream and downstream of the mine
- Bank erosion caused by bed erosion
- Increased suspended sediment load
- Changes to aquatic habitat
- Changes to groundwater levels caused by changes in the water surface elevation.

There are a large number of case studies that describe infrastructure damage from in-stream mining (Kondolf, 1994; 1997; Rinaldi et al., 2005). Mossa and Marks (2011) comment that floodplain mining is far less regulated than in-stream mining, even though the geomorphic changes that can occur are generally more dramatic.

Mitigating the risks of floodplain gravel mining

Many of the potential impacts of gravel mining relate directly to the responsibilities of river managers, particularly where gravel mines may affect:

- River health
- Floodplain hydraulics
- Riparian vegetation and habitat
- Loss of in-stream habitat

There are also guidelines available to improve rehabilitation of exhausted pits. These include:

- Gravel pit restoration for wildlife (a practical manual) (Andrews and Kinsman, 1993)
- Wildlife after gravel: twenty years of practical research by the Game Conservancy (Giles, 1992)
- River restoration and near-channel gravel mining (Klingeman, 1998).

Where pits are deep and steep-sided, they offer limited wetland habitat and stratification may make much of the water body anoxic (Turner and Erskine, 2005). If pits can be rehabilitated through provision of gently sloping banks, irregular shorelines and with appropriate vegetation, they may offer areas of environmental value

According to mining rules creation of temporary or permanent structures impeding river flows, natural path are prohibited. So is the use of heavy machines in riverbed and in-stream riverbed mining. Similarly, mining operations are not allowed upto 500 metres of up and downstream of drinking & irrigation projects, bridge or barrage structures on the river.