RECOMMENDATIONS FOR A LOWER HASSAYAMPA RIVER MONITORING PLAN

Prepared for

THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
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A monitoring plan for the Hassayampa River should cover the reach from the Gila River to where it exits the canyon near Morristown (herein referred to as the Morristown canyon). This reach of the river consists of a wide floodplain (mostly more than one-half mile in width) with bluffs along a significant portion of the length. The bluffs provide lateral constraint where they exist but in some areas the bluffs are non-existent – for example on the west side of the floodplain in the upper reach and on both sides to the south of the UPRR Bridge. Housing and commercial development was underway near the river in 2006 but has been delayed by the 2008 housing crash and the ensuing recession. This has allowed the District time to obtain new data and modeling that can be used to prepare a monitoring plan and have monitoring in place before the river is greatly impacted by development.

While the current project only covers the Lower Hassayampa River from the Gila River to the CAP crossing this plan covers the entire reach from the Gila River to the Morristown canyon. The plan was expanded to cover the entire reach at no cost to the District since the upper portion from the CAP crossing to the Morristown canyon is part of the same sediment transport reach and problems in one reach will impact the other reach. If differing monitoring plans are implemented or monitoring is implemented in only one reach a serious problem may not be found until it is too late to quickly and economically resolve the issue.

NEED FOR MONITORING

The Hassayampa River is a sand bed river and as such is very susceptible to both lateral erosion and vertical erosion. The absence of gravel and cobbles in the system means that erosion is not limited by the armoring process that occurs in the Salt, Gila, Agua Fria and most other large rivers in the County. The bed sediment is also very deep without cemented layers to limit the rate and depth of erosion. The result of the sand bed with no constraining layers is little resistance to lateral or vertical erosion. This assessment is based on data collected from the Hassayampa River as well as observations of other streams both in the arid southwest and across the United States.

The data collected from the Hassayampa River in the area upstream of the Pioneer pit (above RM 15.6) after the 2010 flood event (approximately a 20 year event) indicated that the headcut / channel lowering from the Pioneer it was approximately 10 to 12 ft in depth at the upstream pit brink and extended 4,000 ft upstream from the pit. The pit is estimated to be approximately 30 ft in depth at the time of the flood event. The data indicate that the channel narrowed and deepened upstream of the pit. These observations confirm the highly erodible nature of the river and highlights the necessity of collecting data to understand the river's current and future stability.

The highly erodible nature of the stream combined with the MAG plans to construct approximately 18 bridge crossings between Morristown and the Gila River underscore the critical importance of the data collection efforts described herein. There will also certainly be pipelines and other infrastructure associated with development that will be constructed across and/or in the river and across its tributaries. This infrastructure will all be at risk if the river becomes unstable with headcuts or tailcuts propagating up or down the river from mining operations or bridge constrictions.

It is R2D's experience that sand bed streams like the Hassayampa are very susceptible to headcutting (channel lowering). This causes rapid changes in both alignment and elevation of the river. Once a headcut starts it can move many miles up the river as well as up the tributaries. The most dramatic was probably on the Mississippi River and the Arkansas rivers where some of these headcuts have moved 200 miles up the river and tributaries (Derrick, 2011). Most headcuts are not that dramatic but a series of headcuts on the Las Vegas wash have eroded 8.5 million cubic yards of sediment from an approximate 9.5 mile reach of the wash (Buckingham, et. al, date unknown, and Las Vegas Wash Coordination Committee, 1999). The Hassayampa River has a flatter slope than the Las Vegas Wash and currently has a large sediment load but too many pits or encroachments could change the rivers regime from a narrow wide flow pattern to a deep narrow pattern which would have major impacts on the stability of the river.

Headcuts on the Hassayampa River don't have the potential to move as far as they did on the Mississippi and the Arkansas but could migrate from the origin to at least Morristown and up the tributaries until they reach a constraining layer. Bedrock control may exist in the river in the river at Morristown that would stop headcuts prior to their impacting the upper river reach but this has not been verified. Other well documented headcut problems in the arid southwest include Rio Puerco in northern New Mexico, the Santa Cruz River at Tucson (as well as an active headcut near Red Rock from Greene's Canal that has not been recently documented (See Haigh 1987) but was investigated by R2D in 2007. There are numerous other rivers and washes impacted by significant headcuts that have been documented across the southwest. A multitude of information can be obtained on any of these sites searching for headcuts and southwest (and/or the river/wash name) on the various Internet search engines.

If headcuts follow the pattern observed in the Midwestern and Southwestern US and along other Arizona rivers and washes, headcutting in the reach below Morristown would move up all of the tributaries above the headcut and impact structures and utilities crossing the river and the tributaries. Headcuts on the tributaries could be significant given the height of the bluffs along the river. These headcuts would move up Jackrabbit Wash as well as the other tributaries both large and small.

Once a headcut starts the sediment removed by the erosive action is transported down the river and then deposited. This can be seen in numerous washes in Maricopa County where serious headcuts are moving up the washes but within a mile or two downstream there is no channel that can be located due to deposition and vegetative growth. The most prominent washes where this has been observed by the author within Maricopa County include: 1) Rainbow Wash, 2) Trilby Wash, and 3) Iona Wash. This deposition of sediment eroded by a headcut would occur prior to the Hassayampa River reaching the Gila River and cause increased flood elevations and expanded floodplains and floodways. This deposition also causes the river to meander and attack it banks which would require additional bank protection. Once the lower portion of the river is developed a headcut in the upper portion can cause millions of dollars in damage and/or maintenance costs to remove the sediment from the river. Stabilizing the river can cost tens (if not hundreds) of millions of dollars if headcuts are allowed to erode without any controls (Buckingham, et. al, date unknown, and Las Vegas Wash Coordination Committee, 1999).

The Hassayampa River from the end of the canyon below Morristown to approximately two miles above the area currently being mined appears to be slightly aggradational (depositional) based on the fact that the active braids are higher than the inactive braids in some locations. If this is the case the river will tend to slowly increase in elevation over time in this reach. This could lead to expansion of the 100 year floodplain as the river aggrades.

The narrowing or constriction of the floodway in the reach below the canyon at Morristown would move the excess sediment currently being deposited in the reach further downstream downstream and cause aggradation in the lower reaches of the river – especially immediately downstream of any narrowed reach.[1] The deposition of this sediment could impact the bridges constructed along the river as well as floodplain elevations. It will be very important to understand the stability of the river in this reach for the design of bridges along the river. If the river is depositional bridge heights must be raised to account for the future deposition. If, on the other hand, mining becomes prevalent along the river or bridges constrict the flow to the point the river begins to erode, bridge piers must be deepened to offset the trend. A monitoring plan will assist in determining if the river is erosional or depositional and if bridges should be designed with additional bridge height or deeper pier depths to protect bridges and other infrastructure along the river.

Based on current modeling and on observed data from the existing mines, the Hassayampa River appears to be relatively stable (other than the mine impacts) in the reach modeled (about 4 miles upstream of Jackrabbit wash to a mile below I-10). The current mining operations caused significant headcuts and tailcuts to form during the January 2010 event. These headcuts and tailcuts do not appear to be in danger of continuing to move upstream and downstream from the various pits at this time. Sediment transport modeling performed in 2006 and 2011 also tends to indicate that the river is currently stable. The stability of the river could change quickly if sand and gravel mining reaches a threshold where a headcut begins to move up the river away from the pits or tailcuts begin to propagate down the river. Given the limited number of flows that

[1] An example of this was found in the Santa Rosa Wash at Maricopa after the 1983 flood (Rhoades 1990) where the sediment eroded from the channelized reach was deposited at the downstream end of the channelized reach – See Page 172 for an aerial photo of this phenomenon.

occur on the river it is important to understand the behavior and stability of the river so that future changes in river stability can be expected and planned for.

Based on the amount of infrastructure planned and the erosive nature of the river it is recommended that the river be monitored for erosion and deposition problems. This monitoring should focus not only in the areas surrounding both active and inactive mining operations but also away from the mining operations. A monitoring program will help to locate any changes in river stability before the problems become major concerns.[2]

MONITORING RECOMMENDATIONS

Monitoring should be required in areas that have been impacted by mining to be sure that headcuts and tailcuts do not propagate up or down the river from the pits. In areas where mines are located in series (such as the current Hanson, CEMEX, and Pioneer pit (RM 12, RM 13.5 and RM 15.5) monitoring may be reduced such that the series of mines are monitored in combination rather than separately. For example rather than monitor upstream and downstream of each pit individually the number of monitoring sites could be reduced to be upstream and downstream of the series of pits with a site between each pit rather than upstream and downstream of each of the individual pits. Monitoring near mines is anticipated be incorporated into the semi-annual sand and gravel permit inspections.

Additional sites could be located where bridges are anticipated with the intent that monitoring after bridge construction could be handled by MCDOT or ADOT depending on which agency owns the bridge to avoid duplication of effort. This monitoring would be done as a part of their normal bridge inspection programs but coordination would be required to ensure that the data was included in the District's monitoring database. The monitoring of these sites would allow the analysis of the impact of the bridges on river stability and width. This information could be invaluable in the future to aid in the selection of proper bridge lengths for later bridges across the river.

Monitoring is also highly recommended for areas where no mining has occurred and away from the areas where bridges are expected to be located. These additional points should be away from the impacts of sand and gravel mining to allow the determination of the long term trends of the river due to natural processes. These points should be spaced all along the reach from approximately the Morristown canyon to the Gila River confluence.

The specific monitoring recommendations that follow should allow the District to determine if permits should be amended, new permitting suspended, additional mining allowed, and/or protection or mitigation measures taken to protect the river and

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[2] The Las Vegas wash is an example of small problems becoming major problems. The replacement of a culvert with a bridge started a 25-30 ft headcut that has moved up the wash. Current estimates to simply stabilize the wash in its current condition are in the $110 million range. The sediment from the wash forced the relocation of a marina on Lake Mead and has caused immense damage to infrastructure along the wash and on its tributaries. The original headcut could have been stabilized for approximately $70,000.

infrastructure along the river. This monitoring plan will allow the District to have early notice of potential problems as well as develop baseline data to better understand the behavior of the Hassayampa River in the reach below Morristown[3].

The monitoring program described in this report will:

1) Allow early detection and tracking of potential problems where delayed detection may result in problems that are much more costly to repair,
2) Allow early repair and/or containment of problems before they become system wide problems,
3) Allow the District to adjust mining and other permits to account for changing river conditions when problems begin rather than later when any problems and challenges have grown to become major concerns, and
4) Build on existing District visits to the river by piggybacking the collection and documentation of data on other tasks being performed along the river to the extent possible.

Results that would cause the District to review the data from the monitoring program more closely would include:

1) Changes in thalweg depth away from pit locations,
2) Changes in thalweg depth that are not expected near pits – i.e. substantial changes in thalweg elevation or channel cross section[4],
3) Changes in river alignment near mining pits,
4) Capture of the channel by overbank pits, or
5) Other significant changes to the river thalweg elevation or planform.

PROPOSED MONITORING PLAN

The following actions are recommended as a part of this plan. Three areas are specified for monitoring: one for areas near active and inactive mine operations, one where bridges are anticipated to be constructed and one for areas that are not expected to be disturbed

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[3] River Research & Design has observed that many governmental agencies and business organizations function in a reactive mode – that is they react to problems as they occur or as the agency becomes aware of the problem. By the time the problem becomes apparent it is usually larger and more costly to fix that if it were caught early and the problem resolved. This causes the agency to spend more money and expend more resources to react to the problem than if the agency were to have a monitoring program (an early warning system) to detect problems that may be starting in the river system. This monitoring plan serves as an early warning system for problems in and along the Hassayampa River. By implementing this monitoring program the District can be aware of problems in their early stages when small actions may be able to either reduce or eliminate the problem. Problems that are not addressed early may require a much more substantial commitment of resources to correct. It also allows the District to program resources rather than reacting to an emergency situation.

[4] A substantial change is defined here as more than maybe 2-3 feet in thalweg elevation or vertical banks on both sides of the river indicating down cutting. It could also be a change from a broad shallow cross section to a deeper narrower cross section. This will take some training of staff if they do not understand river morphology and what constitutes a substantial change in the cross section. It is expected that this will require those with experience on the river to interact with those who are expected to observe the river and make this determination. It is hard to define substantial and it will require some experience to determine if a change is substantial or not.

by mining or bridges. The non-mined areas are designed to provide baseline data and to provide early indications of systemic problems that may be starting in the river.

Areas near Active and Inactive Mining Pits

Monitoring in areas with active mining pits should concentrate on the areas at the boundaries of the mine owner's property. It is anticipated that a surveyed cross section will be located at both the upstream and downstream property boundary and extend across the entire floodplain. It is especially important to survey the entire floodplain at these locations on the Hassayampa River to insure that the river does not avulse from one channel to another on the opposite side of the floodplain that has not been previously surveyed. This switch would make earlier data sets almost worthless if the data does not cover the entire floodplain. If data is collected across the entire floodplain the change in flow path would still be within the collected data and the earlier data sets could still be used for analysis. Surveys should also include a survey line from the property boundary to the brink of the pit along the river thalweg such that the pit(s) headcut and tailcut can be documented.

Additional data should be obtained at these locations including photos taken from fixed locations that show the river looking across the channel, across the floodplain, upstream, and downstream from the point. These photos should be taken at least annually at times that will generally match the annual aerial photography cycle the county uses.

Photos should also be taken at the pits that indicate the depth of the pit below the floodplain and/or channel. Photos should include upstream, downstream, across the floodplain (both ways) and any other views that may be of interest or show changes in the river channel. Areas showing erosion or deposition should be included in the photos. The majority of this data would be collected during the District's semi-annual mine inspection visits. The photos should be taken from fixed locations to the extent possible and all photos should be referenced to GPS points.

Areas near Future Bridge Locations

A fixed cross section should be located near future bridges so that the behavior and trends of the river at the bridges can be determined prior to bridge construction. This will allow the District and MCDOT to view the impact of bridges on the stability of the river at the bridge crossings. Each site should consist of a surveyed cross section with fixed starting and ending locations. The cross section should include the entire 100-year floodplain to ensure that the river does not avulse outside of the original cross section. An avulsion outside the original cross section would make data collected prior to the avulsion nearly worthless. The surveyed cross sections should be located such that bridge construction will not disturb the locations if possible. An alternative is to locate the sections such that they will be at the bridges and can be easily located after construction is complete. Given developer aversion to straight roads and grids it is almost impossible to predict if a monitoring location will be at a bridge or not once developers begin to design their neighborhoods and main roads.

Again photo records should be taken at a fixed locations looking upstream, downstream, across the channel, and across the floodplain. The fixed location could be from a fixed GPS point or a permanent monument. Any features of interest or features that appear odd should also be photographed and referenced to a GPS location.

Locations away from Pits and Bridges

A number of locations should be selected that are not expected to be mined or disturbed by bridge construction. These sites will provide long term data regarding stability of the river away from disturbances. The sites where disturbance occur will be used to gage impacts from mining and bridge construction but sites that are undisturbed will give warnings of system wide changes in the rivers that are caused by mining, bridges, or encroachments from development. The data from these points will be important in determining if changes are beginning that may impact the entire river reach. These system wide variations are the changes that result in major problems and costs for containment or repair.

These locations should also have a photo record developed with photos looking upstream, downstream, across the channel, and across the floodplain. A series of photos (or digital video) showing the view in a 360 degree circle from the point would be a good idea. That way if changes occur all of the angles have been taken and can be compared. Any significant or odd occurrence should also be photographed. All photo points should be referenced to GPS points.

Overview and Summary Table

This monitoring plan is designed to be a starting point for monitoring of the river. It is not intended to be a fixed plan that cannot be changed but rather a start that can be modified as the monitoring program goes forward. It is anticipated that the plan will be changed as data is collected and more information is gathered and understood. Cross sections may be added or dropped and recommended intervals may be changed as conditions along the river change or indications of problems appear. The recommended initial timing of monitoring activities is shown in Table 1. The monitoring plan should be updated as required but at least every five years during a review of the river stability and status.

Table 1. Monitoring Tasks and Timing.

	Location		
Item	Mining Pits	Bridge Locations & Future Locations	Undisturbed Locations
1. Location	Upstream and Downstream Property Boundaries	Either at bridge locations or just upstream of bridge locations	A minimum of about ¼ mile from bridges and mining operations
2. Photos Annually and after events[5] (if >1,000 cfs events then semi-annually)	360 degree photo record taken annually at fixed location and specific photos of odd or interesting items	360 degree photo record taken annually at fixed location and specific photos of odd or interesting items	360 degree photo record taken annually at fixed location and specific photos of odd or interesting items
3. Channel Inspections	A visual inspection of the inlet and outlet channels to the pit looking for evidence of significant headcutting or tailcutting (>2-3 ft vertical walls, etc) (>2,000 cfs @ I-10)[5]	A visual/photo inspection of channel if surveyed cross sections indicate significant changes to the thalweg elevation. (>5,000 cfs @ I-10)[6]	A visual/photo inspection of channel if surveyed cross sections indicate significant changes to the thalweg elevation. (>5,000 cfs@I-10)[5]
4. Surveyed Cross Sections	Surveyed Initially and then after events	Surveyed Initially and after events + profile (>5,000 cfs[5,7])	Surveyed Initially and after Events + profile (> 5,000 cfs[5])
5. New Topographic Mapping	After Events > 10,000 cfs (I-10)[5]	When significant changes noted in surveyed cross sections (changes more that about 2-3 ft in elevation across the channel or significant planform changes)	When significant changes noted in surveyed cross sections (changes more that about 2-3 ft in elevation across the channel or significant planform changes)

[5] Ideally the photos would show the pit with no water in it so the shape of the deposition can be noted.
[6] All flow values could also be keyed to the Morristown gage but flow values would be higher than those at the I-10 gage to account for channel losses. Numerous Morristown flows do not reach the I-10 gage.
[7] The value of 5,000 cfs was selected based on changes that occurred during the 2005 flood event. These changes included filling of pits and erosion upstream and downstream of the mining pits. This value can be adjusted if it appears that too many resources are being allocated when only minor changes occur.

Additional Recommendation and Explanations

1. Location. The monitoring plan anticipates monitoring stations will be set up at three types of locations:

a. At the upstream and downstream boundaries of mining properties that are (or have been mined). This station will be for monitoring of river channel changes that may migrate off-site as a result of mining operations. The monitoring sites should be located at the upstream and downstream property boundaries in order to have early warning of headcuts or tailcuts moving off from the property. These sites are in accordance with the permit requirements that no more than one foot of scour be allowed to leave the property. These sites are not anticipated to be linked directly back to the mining permits unless serious erosion problems are noted. Additional cross sections could be obtained near the upstream and downstream pit brinks to facilitate future modeling. A survey line following the thalweg from the property boundary to the pit brink should also be obtained to aid in future modeling efforts.

b. At (or near) proposed bridge locations. These stations should be located in the general vicinity of expected bridges and road crossings. The selection of these sites should be based on regional plans and proposed bridge crossings. It is recommended that the cross sections be placed as close to the proposed bridge sites as practical. It is anticipated that some of the planned bridges may be moved up river or down river or may not be constructed within the current planning horizons. Monitoring should continue at sufficient sites such that any problems with the river can be detected early.

c. Between bridge locations where mining operations are not expected. The selection of these sites could be problematic. It is suspected that much of the river not crossed by bridges will ultimately be mined. The areas where these stations are placed could well be proposed for mining in the future. Thus a good selection of these locations and the bridge locations should be monitored so that a reasonable number of monitoring sites will remain relatively undisturbed well into the future to provide good monitoring data.

The monitoring stations should include cross sections with monuments at each end of the cross section (outside the boundaries of the floodplain) and may have associated GPS points where photos are to be taken. The cross sections should include the entire floodplain and any side channels or split flow reaches.

2. Photo Documentation and Review. Photo documentation of areas near active and inactive pits should occur annually in conjunction with regular District Inspections. If events greater than 1,000 cfs at the I-10 gage occur the photo record should be taken semi-annually. The timing of photos can be adjusted as necessary based on changes to the river and flood flows. The photographs should be taken from fixed locations to the extent possible. These locations could be established using GPS coordinates and/or permanent monuments and should include areas where the river/tributaries enter the pits, the river and braids leave the pits and any areas where erosion is occurring on the pit walls from the river flows. Photos not taken at fixed GPS points should be referenced to a GPS point. The use of a camera with GPS capabilities would facilitate this effort.

If active erosion is present at a mine site it may be advisable to photograph the areas more often and after even relatively minor events. Active erosion can be seen by vertical banks on one or both sides of the channel, the formation of gulleys, or the formation or movement of headcuts. If no erosion is taking place it may be acceptable to photograph the areas in alternate years but it is recommended that the areas be photographed annually if possible to match the Counties annual aerial photography cycle. This will allow the correlation of ground photography with the aerial photographs.

Photos that indicate depth of the pits should also be obtained (i.e. photos with equipment or people that can be used to estimate pit depths). Photos could include areas where an object is located that can be used to estimate bank heights, areas where a marked rod can be placed against a bank, or areas where lateral retreat can be estimated from the photos.

Annual Aerial Photos. The Counties annual aerial photography data should also be reviewed to see if any problems are apparent from the air. If no events have occurred on the river this review could be waived. When new aerial photography is obtained for this reach of the river the location and flow path of the river should be reviewed to see if any major channel realignments have occurred or if bank erosion or significant channel changes are visible in the aerial photos.

In reviewing the aerial photo data the movement of the channel from one side of the floodway to another should not cause undue alarm but a site visit and survey should be performed to set the new baseline elevation of the relocated channel. If other changes (i.e. lateral widening/narrowing or vertical erosion) are occurring a more detailed onsite channel inspection may be required to determine the level of additional monitoring required. If the changes are determined to be significant more frequent monitoring should be initiated and/or a survey undertaken.

If problems are noted during the semi-annual pit inspections further investigation should be made even if no flows greater than 1,000 or 2,000 cfs have occurred.

3. Channel Inspections. The inspection of the channel at the various locations should occur annually for locations upstream and downstream of pits. These should occur at the same time the photo record is being prepared and on the same visit. This would most likely be done during the semi-annual pit inspections currently being performed by the sand and gravel mining staff.

This task simply involves looking at the channel for evidence of new erosion features such as vertical banks or deposition along former vertical banks. The movement of the channel laterally would also be something that would be noted. This information should be entered in a field notes form that becomes a part of the permanent record for the monitoring station.

The inspection and accompanying photo record should include the condition of the main channel, main channel braids and tributaries that enter both active and inactive mine pits. This inspection should be made after flow events and should be timed such that the changes due to erosion have not been obliterated by continuing mining operations. These inspections would consist of a walking/driving inspection to view headcutting, lateral erosion problems or other indications of channel instability.

4. Surveyed Cross Sections. After events over approximately 2,000 cfs the cross sections near the pits should be surveyed to determine if change have occurred. It is anticipated that this flow rate could be raised if no changes are noted but the triggering flow rate probably shouldn't be raised above 5,000 cfs to insure that changes are not missed. The cross section surveys at the boundaries of the mining properties should also include profiles from the property boundary to the edge of the pit to capture changes in the channel elevation. The profile should follow the thalweg to the extent possible.

Surveying for monitoring stations that are not located near pits could be limited to occur only after events of 5,000 cfs or more (approximately a 10 year event). This flow is based on the flow that caused significant headcuts in the channel in 2005. This value could also be raised if no changes are being noted and surveys could be limited to either when visual inspections note changes or after 10,000 cfs events (approximately a 20 year event). This same monitoring recommendation would apply to both bridge and non-bridge stations.

5. New Topographic Mapping. New topographic mapping would be indicated when visual inspections or surveys indicate significant changes in the channel elevation or location. It is recommended that the initial flow trigger near the pits be set in the range of the 2010 event or 10,000 cfs (approximately a 20 year event). This could be varied if necessary but events of this order are large enough to cause significant changes to the Hassayampa River bed near mining pits as seen in the 2010 flood event.

6. Detailed River Review and Monitoring Plan Update. At five to ten year intervals a more detailed review of the river should be performed. This review will include all survey data, photo data and observations that have been obtained in the previous five year period. A tour of the river would be scheduled so that the District staff can observe any problems that may have been missed in the annual photo records and other data collection efforts. This review will provide an opportunity to focus on the river and any problems that have become apparent or that may become apparent on closer review. If no scour, deposition, lateral migration, or other problems are apparent the review would be a simple site visit and notation that no problems were noted. If erosion or other problems become apparent solutions should be investigated and programmed before they become system wide problems.

This river review would also be a time to update the monitoring plan to add or drop sites, modify schedules and add or delete tasks from the monitoring plan. It is anticipated that this review would involve the District personnel involved in sand and gravel permitting, river mechanics, and planning.

7. Update Monitoring Report. The monitoring report should be updated annually (or semi-annually) with the field inspection forms and photo records. This material may be digital and include the photos from the inspection(s) in digital form labeled as to the date they were acquired as well as the location. The use of a GPS enabled camera would facilitate this effort. Any surveys (both aerial and ground) obtained should be referenced and file paths and file names recorded (or perhaps stored on digital media) so data can be easily found for later use. The proposed locations for monitoring sites are shown in Figure 1 and the locations are further explained in Table 2.

8. Institutionalization of the Plan.

The plan, once adopted, should become a part of each branch's / division's operating plan such that whenever the river is visited the data is collected, reported, and retained. If one part of this process fails the data will not be available for review and early warnings will not be given or heeded. The monitoring plan needs to become a part of the District's plan of operation such that it is continued and updated regularly. The plan can be adjusted to focus on specific areas once data is being collected and a baseline condition is established. This plan needs to be adaptive and not rigidly fixed based on these initial thoughts, data, and the analysis performed up to this date in the preparation of this plan.

It is anticipated that different branches of the District will become responsible for different portions of the plan. The sand and gravel mining inspections will handle the areas near the pits while other branches may handle the locations away from the pits. The crews maintaining the ALERT stations may handle locations associated with or near gages since they will be in the area already. This may also give the ALERT program more information regarding the history of the gage and channel modifications. Other branches would handle other monitoring functions. When cross section surveys are necessary the District's survey crews would be called on to obtain the cross section data and when staff from the engineering staff visit the river they could also provide data for the monitoring record. Much of the data could be obtained during trips that occur as a result of normal District activities.

9. Specific Recommendation for 2011 to 2016.

Pioneer Pit. The existing headcut from the Pioneer pit should be monitored to see if it continues to lengthen and deepen or if it begins to fill. Since the pit did not fill during the 2010 event the headcut may continue to extend and possibly deepen. This pit is the only area of significant concern *for the moment* on the river. For the 2010 conditions the cross sections would be located at the upstream property boundary but profiles would be collected with any cross section survey that is performed. The Pioneer pit is the most upstream pit in a series of pits located close together and any problem with headcutting will be readily noted at the cross section upstream from the pit. The downstream property boundary should also be surveyed to insure that the headcut from the downstream CEMEX pit and the tailcut from the Pioneer pit do not continue to lower the downstream brink of the Pioneer pit.

Hanson and CEMEX Pits. Surveys should be performed as suggested at the downstream and upstream property boundaries after large events (>5,000 cfs). After events > 2,000 cfs visual inspections should be performed to see if significant changes have occurred. If significant changes appear near the pits, surveys should be obtained as well as thalweg profiles into and out of the pits. Since these pits have mostly filled and no active mining has been resumed it is likely that no significant changes will occur until mining resumes. Profiles reaching to approximately I-10 should be taken with any cross section data below the Hanson pit to insure the tailcut does not move down the channel. Given the sediment load in the Hassayampa River it is not anticipated that it will. The data described in this section will be some of the most important in providing early warning of impending problems.

Hassayampa River Monitoring Locations (Proposed)

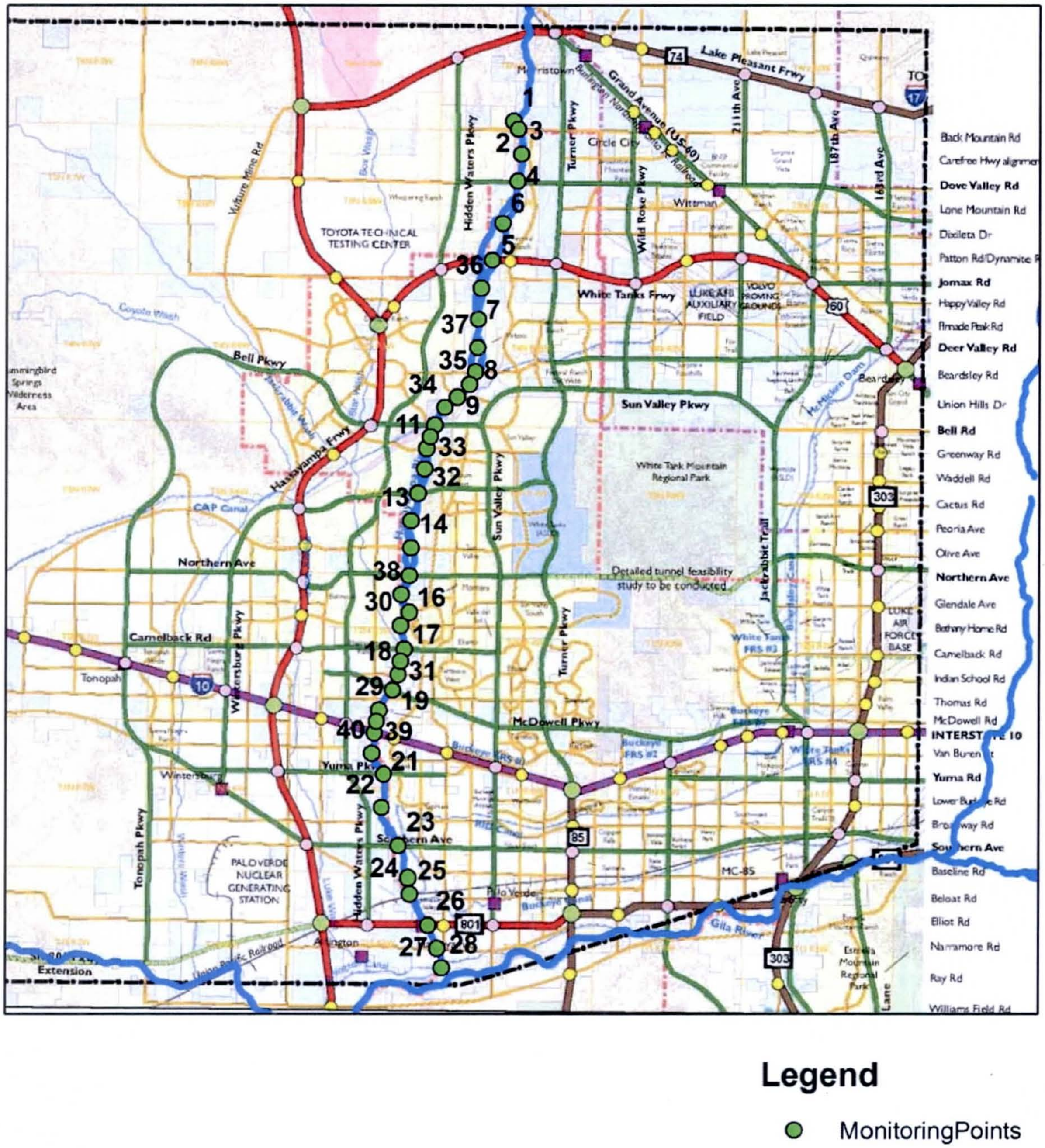

Figure 1. Proposed Locations for Monitoring Sites.

Table 2. Locations for Monitoring Sites

Station	Location	Bridge	No Bridge	Pit
1	North of Black Mountain Road		X	
2	Black Mountain Road Alignment	X		
3	Carefree Highway Alignment		X	
4	Dove Valley Rd	X		
6	Btwn. Dixileta Dr/Lone Mtn Rd		X	
5	White Tanks Freeway	X		
36	Below Jomax Road		X	
7	Pinnacle Peak Rd		X	
37	Approx Deer Valley Alignment		X	
8	Deer Valley/Beardsley Rd	X		
35	Below Beardsley/Deer Valley		X	
9	Union Hills Dr	X		
34	Above Bell Pkwy		X	
10	Bell Parkway	X		
33	Below Bell Pkwy		X	
11	Greenway Rd	X		
32	Above Wintersburg Pky		X	
12	Wintersburg Pkwy	X		
13	Peoria Ave		X	
14	Olive Ave	X		
15	Northern Ave	X		
38	Approx Glendale Alignment		X	
16	Above Bethany Home Align.		X	
30	Above Pioneer Pit			X
17	Camelback Rd	X		
31	Between CEMEX and Pioneer Pit			X
18	Indian School Alignment (above CEMEX pit)			X
19	McDowell Pkwy	X		
29	Below Hanson Pit			X
39	Above I-10		X	
20	I-10 Bridge/Gage	X		
40	Below I-10 (probably no pit)		X	
21	Yuma Parkway	X		
22	Approx Lower Buckeye Rd			
23	Southern Ave		X	
24	Approx Baseline (may need US/DS)	X?		X?
25	UPRR Trestle	X		
26	801 Freeway	X		
27	Hassayampa Rd	X		
28	Below Hassayampa Rd		X	

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