APPENDIX J: GEOMOPHOLOGIC OPINION ON FEASIBILITY OF STREAM NATURALIZATION-THE LOWER ARROYO SECO

Geomorphologic Opinion on Feasibility of Stream Naturalization: The Lower Arroyo Seco.

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Introduction

The purpose of this contribution is to provide an independent geomorphologic opinion on the feasibility of naturalizing the lower Arroyo Seco between Devil's Gate Dam and the confluence with the Los Angeles River. Secondary goals are to comment on the feasibility of removing Devil's Gate Dam, and to suggest future strategies to advance this project to the final design stage. This report is intended to add an earth science perspective to the engineering and biologic work presented in this report.

Naturalization of Stream Channels in Urban Settings

Compared to designing concrete channels, restoring urban streams is complex. When designing concrete channels, the major challenge is not to prove technical feasibility, because it can be assumed that it is possible to construct a channel conveying any amount of discharge that may arise. A known set of standard solutions are available, and, once the surrounding hydrologic and hydraulic conditions are known, the major feasibility concern is that of cost.

When restoring streams to a natural condition we have to worry about bank erosion, bed scour, roughness, sediment transport and many other complex issues. The constraints on stream restoration in urban settings are substantial and the "concrete engineering" assumption that we will find acceptable design solutions is not at all warranted. Complete stream restoration is generally unrealistic and many compromises have to be made often resulting in streams that are not restored in the strict sense of the word. The term "naturalization" is used because it implies the restoration of viable natural ecosystem functions, rather than the return of a stream to exactly what it was before.

In the case of the lower Arroyo Seco we know that complete restoration is not feasible because substantial portions of the floodplain are urbanized. It would be unrealistic to devise a plan that removes all urban structures from the geologic floodplain. This means that historic knowledge of the natural characteristics of the channel and the floodplain cannot serve as blueprints for future restoration, making the design of a naturalized channel substantially more difficult. Final design requires a juggling act between restoration goals and physical constraints. In order to come up with valid design ideas one has to carefully define restoration goals, understanding that there are technical limits and that prospective design solutions must be carefully tailored to fit the individual stream. These design solutions are never self-evident often demanding a "holistic" treatment of the watershed with a substantive understanding of complex inter-related processes.

The tremendous opportunity of the Arroyo Seco Watershed Restoration Feasibility Study (ASWRFS) is that it provides a detailed compilation of knowledge of all processes within the watershed. This allows comprehensive planning, producing results that are otherwise unattainable when only limited or disconnected portions of the stream are treated.

Restoration Design Goal

The report provided by the engineering firm of Montgomery Watson and Harza is a comprehensive summary of the hydrologic and hydraulic conditions of Arroyo Seco. Using this information, together with results produced in the reports on habitat and water resources, the definition of stringent restoration goals is possible. The more important recommendations for the design of a naturalized channel would be the following:

a) A continuous naturalized stream corridor from the confluence to the San Gabriel Mountains that provides habitat connectivity. This goal has probably highest priority from an ecological perspective.

b) “Soft” or quasi-natural channel design that controls grade by inclusion of sinuosity and large roughness elements such as boulder bars and pool and riffle sequences.

c) Maximum vertical drops of 8 ft. with adjacent pools of a depth of at least 1.25 times the barrier height. These drops exist only in the high flow portions of the channel. The low flow channel has maximum naturalized drops of 1.5 ft built as boulder riffles.

d) Riparian tree vegetation along the low flow channel that provides for in-stream cover and water temperatures below 80^{o}F.

e) Sediment transport large enough to maintain the low-flow channel.

f) Continuous water flows of 0.5 to 1 cfs during summer months to maintain a minimum perennial riparian plant environment (various sources)

g) Flow velocities below 10 ft/sec for the 10-year flood.

h) Utilization of floodplains for flood attenuation.

i) Utilization of all recreational facilities for flood attenuation where flow velocities can be held below 5ft/s.

j) Sub-critical flow up to the 25 year flood.

k) Two-year storm produces continuous 1ft deep flow along entire stream.

l) Erosion control provided by erosion-control blankets (ECB), turf-reinforcement matting (TRM), and articulating concrete block (ACB).

m) Minimization of concrete-design solutions.

n) Soft-bottom box channel as the worst case scenario.

Following the completion of this report, this list may have to be revised during a thorough review by the ecology/habitat team. However, it must be emphasized that the adoption of a list of design goals is absolutely necessary for a meaningful feasibility analysis of local design solutions. Since a standard set of design solutions are not available in stream restoration, the question of whether these goals can technically be achieved using naturalized channel design-methods has not been answered yet.

Flood Peak Attenuation and Benefits of Floodplain Storage

Stream restoration and the overall success of naturalization projects often hinge on whether it is possible to manipulate peak flows enough to make “soft” channel design solutions feasible.

Natural stream systems attenuate peak flows by utilizing the floodplain as additional, temporary storage for excess floodwater. This reduces the amount of stream channel erosion and, subsequently, the stream channel evolves to attain a delicate equilibrium form, accommodating all flows, from small to very large. Much of stream restoration is focused on widening the stream channels again to utilize this process, thereby stabilizing the system by reducing flow velocities caused by overly high flood peaks. While the total volume of flood flow does not change, average flow velocities become smaller as flood flow is extended over a longer period of time.

One of the advantages of creating a comprehensive master plan for the entire watershed is the fact that management and structural measures can be implemented in the tributaries and upper watersheds that make restoration of the main channel feasible through lowering of flood peaks. MWH have rightfully pointed to best management practices in treating tributary flow. Clearly, comprehensive treatment would have to include reducing the impervious surface areas within the tributary watersheds to reduce runoff and peak flows. Other, more structural measures within the tributary channels and at the confluences can be used to further slow and attenuate flood peaks.In the lower Arroyo Seco system there are three major ways to accomplish flood attenuation that may allow more beneficial channel designs:

1. Changes in release patterns at Devil's Gate dam.
2. Reduction of tributary flows through best management practices and the structural implementation of flood detention.
3. The maximization of cross-sectional areas of the naturalized channel to increase the in-channel storage.

Removal of Devil's Gate Dam

An extended goal of flood attenuation, as briefly discussed in the MWH report, is the possibility that enough attenuation is provided so that Devil's Gate Dam becomes obsolete. From an environmental perspective this would be highly desirable because it would create the highest degree of habitat connectivity. Removal of the dam may even be beneficial to the County because dams are expensive to upgrade and maintain. Further, they may require other substantial costs due to sediment build-up, and other environmental problems that have to be dealt with. Devil's Gate Dam only provides an attenuation benefit of 5,000 acre-feet of storage and may not be worth the accruing management cost for decades to come.

MWH made some rough estimates on the potential benefit of inundation of floodplains to attenuate flood peaks. Their estimates shows that a very wide floodplain area adjacent to the main channel must be inundated by 10 ft along the entire lower Arroyo Seco to replace the storage provided by Devil's Gate Dam. It appears that their preliminary sentiment is that the existing area available for restoration would be inadequate.

Another reason why this is probably correct is because large floodplain flows at depths of 10 ft can be quite erosive and can only be controlled through the introduction of massive roughness elements. Even if it was possible to inundate the floodplain by 10 ft, it would be necessary that flow velocities on the floodplain be impeded sufficiently to prevent massive erosion. If grassy golf courses, recreational areas, and parking lots were integrated into the new floodplain areas, roughness would unlikely be high enough to prevent supercritical (rapid or shooting) flows on the floodplain at the current flood channel slopes of 0.016-0.011. Hence, it is probably safe to say that for the Arroyo Seco, attenuation of flood peaks by dramatically increasing the channel cross-sectional area is not a promising alternative to flood storage at Devil's Gate Dam. If the floodplain had significantly lower slopes this may be possible. This can only be accomplished through massive grade control structures that may constitute obstacles to fish migration and habitat connectivity. As flow depths and flow widths become large, significant longitudinal distances between grade control structures, and an increase in height are required to reduce water surface slopes and erosive shear stress on the flood plain surfaces.

However, flood attenuation can also be produced through detention in naturalized and landscaped basins adjacent to the newly constructed channel and floodplain. These detention structures can store flood volume from tributary drains and can accommodate overflow from the main channel and active floodplain. The advantage of landscaped detention structures is that they do not have to withstand high flows and can serve multiple purposes such as flood control structures, recreational facilities (golf courses, parking lots, pick-nick grounds, practice fields). They can be designed to include naturalized permanent wetlands that are aimed at intercepting irrigation and street drainage, thereby improving water quality.

For the lower Arroyo Seco area, maximum attenuation can be achieved in the careful apportionment of attenuation benefits between active floodplain storage and flood detention basins. In the Rose Bowl area, for example, this would mean the design of a naturalized channel cross-section that prevents supercritical flow up to about the 25-year flood (~6,000 cfs). Flows larger than this would over-flow into detention areas that simultaneously intercept tributary flows. The main channel would have to be carefully designed to turn supercritical at about the point when detention is maximized. Upon turning super-critical the main channel will likely convey very large discharges. This flow would erode the low flow portion of the channel, however, this is comparable to natural processes where this process provides for rejuvenation of the riparian system. The final size of the attenuation basins will determine how often this occurs. If the final engineering flow model shows that this design is hydraulically feasible, and attenuation benefits can be maximized along all remaining flood plain areas that are presently used for recreational purposes, the removal of Devil’s Gate Dam may become a possibility.

Currently, the open and recreational space between Devil’s gate dam and the confluence is about 740 acres. If half of this space was inundated by 10 ft during the capital storm (this includes the area apportioned for the main channel), the provided storage volume would be about 3,700 acre feet. The removal or replacement of Devils Gate Dam would have to be performed in such a fashion that the remaining floodplain within the Hahamongna Watershed Park would accommodate the remaining 1,300 acre feet of storage that are now provided by Devil’s Gate Dam.

This scenario requires that all achieved attenuation benefits are used for the removal of the dam. This may be impossible if reductions of peak flows are required to design a naturalized stream channel that accommodates the design discharge in the first place. Realistically, the engineering and geomorphic design teams will have to embark on an extended process of iterative design improvements that maximize attenuation. The removal of the dam may become a realistic possibility, but would have to be a secondary goal following substantial improvements within the watershed that are all geared toward reduction of peak flows.

Design Discharge

It is important to realize that establishing a “design discharge” is the single most important piece of information that decides feasibility from a hydraulic perspective. One of the technical difficulties in designing naturalized channels is that natural materials rarely provide the resistance to erosion that concrete does. Nevertheless, restored channels should provide a degree of flood protection that is comparable to existing conditions, and in some cases the Los Angeles County Department of Public Works (LACDPW) requires that new structures withstand the “Capital

Storm Runoff". The United States Army Corps of Engineers routinely gets involved as they also have jurisdiction over the Los Angeles County drainage system. Both agencies have different standards with regard to required flood protection and both agencies are in the difficult position that they have an obligation to protect the public from floods and to protect the environment at the same time.

The theoretical concept of a "Capital Storm Runoff" (equivalent to the Probable Maximum Flood) was developed early last century when historic weather and stream-flow observations were inadequate to make solid statistical predictions of the probability of floods. The idea was to create a "worst case" scenario based on observations of rainfall that were available. At the time, the worst storm was based on observations of about 50 years at a small number of weather stations. Ultimately, the 50-year rainfall total over a 24-hour period was adopted to represent this "worst storm", the capital storm. This storm is assumed to be homogeneously distributed over a watershed with saturated soil conditions from three previous days of rainfall. The amount of rainfall is used in a rainfall-runoff model that crudely estimates how quickly and how much of the storm water will concentrate in the stream channels to produce floods. Runoff is strongly dependent on estimated runoff coefficients that determine the degree of infiltration.

While rainfall data have improved over the years, the initial assumptions of the procedure remains quite unrealistic. It is improbable that a 50-year rainfall amount is produced homogeneously over an entire watershed after three previous days of rainfall. Likewise, the generation and timing of runoff is extraordinarily difficult to predict, even for well-studied experimental watersheds, where runoff-coefficients are measured, not estimated.

The statistical likelihood of a Capital Storm Runoff is generally unknown. Although a 50-year storm is used as input, the likelihood that this storm is homogeneously distributed over a watershed is unknown. Many engineers and hydrologists agree that the Capital Storm is not realistic. Many scientists believe that this scenario is physically impossible and increasing evidence from measured flood frequencies at gaging stations substantiate this assertion.

Stream-gage data produce more reliable estimates of flood frequencies because they are direct measurements of flows. As the measured time series become longer, these data produce more realistic pictures of the actual likelihood of certain floods. When comparing the predicted runoff values with measured flood records it is striking that the capital storm runoff is customarily far greater than the 100-year flood. As MWH point out in their report, the capital storm runoff amounts to a factual 450-year flood at the confluence with the Los Angeles River. Clearly, a requirement to build a 450-year channel at the confluence amounts to an arbitrary demand in light of the fact that this defies any reasonable cost-benefit consideration, and that this will result in unnecessary protection at taxpayer's expense.

As unrealistic as the procedure may be, it is important to point out that the sole purpose of this type of estimates is to provide flood-protection. Floods are the greatest natural hazard we face in the United States and conservative measures are required as routine administrative procedures to ensure safety. In larger projects, however, it becomes feasible to look at realistic probabilities to determine design discharges to insure protection.

The reason why this topic is so important for this work is the fact that a capital storm runoff-requirement may make comprehensive stream restoration technically infeasible. Even natural streams without width limitations are rarely capable to handle such large discharges without sustaining massive erosion and lateral migration. Hence, the difficult question for the County and the Army Corps is to weigh their respective responsibilities to flood protection and environmental quality in a way that satisfies both.

Concessions with respect to strict design discharge requirements were made in the past. In their review of the L.A. County Drainage Area the Army Corps have conceded that flood protection as low as the 75-year flood was acceptable when cost-benefit analyses indicated this to be prudent. This, in spite of their recommendation that the 133-year flood is the future goal for design discharges. Similarly, the County has not always set highest priority on upgrading of channels that are significantly "under-fit" with respect to the capital flood. This can be interpreted as an implied agreement that the capital storm runoff cannot always be considered the ultimate criterion to ensure flood protection.

For the continued progress of project it is important that the County and the Army Corps are involved and that they are asked to make statements as to what their design discharge requirements are for the various reaches of the lower Arroyo Seco. Substantive feasibility analysis and naturalized channel design will not be possible without certainty of what these requirements are.

Suggested Future Steps

1. Preliminary Design Feasibility

A geomorphic design team should be assembled that accomplishes preliminary plans and strategies that can accomplish the project goals. An extensive catalog of appropriate design measures has to be created that is then tested in a preliminary step. This work must have priority because it is not entirely clear, at this stage, that restoration of the channel using naturalized channel design is possible. There is good reason to believe that it can be accomplished, but, at this point, there are no detailed plans available that unambiguously show that. This step requires that the LACDPW makes some preliminary suggestions about the design discharge.

2. Topographic Data

In order to progress in preliminary or final design efforts, a topographic database for the stream channel and floodplain areas is required. Cross-sections along the entire reach at ¼ - ½ mile increments are needed for preliminary design plans. The LCDPW may have a substantial portion of these data but the ASWRFS team may have to hire a surveyor to complete some missing areas. Cross-section data are the most important planning tool needed to evaluate feasibility. This work must be done quickly so that the preliminary design phase can proceed. An option is to use GPS surveying to produce preliminary cross-sections. Ultimately, a detailed topographic data set should be available within the ASWRFS GIS-database.

3. Hydrologic Models

It appears that the LACDPW has indicated that they are interested in supporting the ASWRFST efforts. They should be asked, if they could complete their GIS-based hydrologic run-off and flow model so that it is available, in its entirety, for this project. Once this model is available, it becomes possible to conduct more accurate tests to determine which prospective design measures will be most successful in attenuating floods.

4. Design and Management Alternatives for Devil's Gate

An independent study has to be conducted that explores design and management alternatives for Devil's Gate Dam. An engineering firm should be asked to evaluate the feasibility of reducing peak flows from Devil's Gate Dam using a number of specified solutions. This must include options available to rout sediment to the naturalized channel downstream to replace erosion losses and prevent long-term channel degradation.

A study conducted by Philip Williams and Associates indicated that the cost of removal of sediment from the Hahamongna Watershed Park can amount to about $1,100,000 per year. The staggering cost of this removal may be an indicator that even structural changes to Devil's Gate Dam, allowing more sediment to pass during small and medium sized floods, may be economically feasible.

Above the allocated 5,000 acre-feet of storage volume, an additional 1,300 acre-feet of storage space is currently available for sediment. This is about half the space that was originally set aside for this purpose. This volume can be used as an attenuation benefit if the LACDPW, the city of Pasadena, and various environmental agencies could agree on a sediment removal program that would allow no further build-up of sediments in the future. The combination of sediment routing through the dam and excavation on a per-need basis could prove a substantial benefit for restoration plans above and below the dam as this would substantially delay and reduce peak outflows from Devil's Gate Dam.

Another insight provided by the PWA study is that infiltration losses within the reservoir during floods may be substantial. This should be investigated in more detail because it could alter the actual outflow pattern during large floods substantially. In fact, it could be considered a direct loss or an attenuation benefit. Strictly speaking, this loss occurs upstream of the dam and could potentially reduce the peak of the inflow flood hydrograph – and this may provide substantial benefits to restoration plans below the dam.

5. Flood Attenuation from Tributaries and Drains

An independent study has to be conducted that explores design and management alternatives for urban storm runoff that contributes peak flow to the main channel. This should focus on the design of detention facilities in the geologic flood plain of Arroyo Seco. One objective of this study is to focus on the largest tributaries and street drains that have the potential to be detained in the geologic floodplain. Deliverables should be specific conceptual design-suggestions at all major locations. The study should explicitly state the expected attenuation benefit of each individual location. This information can be used later to determine the accumulated benefit of these measures for the flood peaks in the main channel.

Summary

After field inspection, review of reports contained in this document, and extensive review of data and literature made available by the ASWRFS team and MWH, it appears that a naturalized channel design of the lower Arroyo Seco is feasible. To make a more affirmative statement additional work needs to be done. This includes the adoption of a firm set of ecological and technical channel-restoration goals. A suggested list of goals was presented in this opinion and needs to be revised by the ASWRFS team. A more precise vision of channel design will be needed so that the question of technical feasibility can be answered unequivocally. This should be done once definite design discharge requirements and a more extensive topographic data set are available. Reduction of peak discharges through various attenuation measures should be investigated independently before the final design stage begins.