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Boulder Dam:
Origins of Siting and Design

Boulder/Hoover Dam is arguably both the most prominent structure ever built under the responsibility of the Bureau of Reclamation and the most famous dam in the world. Originally authorized as Boulder Dam, it was denoted Hoover Dam by Ray Lyman Wilbur (President Hoover's Secretary of the Interior) in 1930; Harold Ickes (President Roosevelt's Secretary of the Interior) reinstated the name Boulder Dam in 1933; finally., in 1947 Congress enacted legislation formally designating it as Hoover Dam, the name it still retains. Whatever the name, the actual structure was built in essential accord with plans developed in the early 1920s. The goal of this paper is simple. It documents: 1) why and when the decision was made to relocate the dam from Boulder Canyon (where it was originally proposed) to Black Canyon (where it was actually built); and 2) when the decision was made to adopt a massive, curved gravity concrete design for the structure. A prosaic goal, but worth undertaking because of the enormous importance of the dam both within the history of the Bureau and within the larger context of American technological development in the 20th century . Because this paper deals with events that occurred during a time the proposed structure was known as Boulder Dam, that is name used in the following discussion.

Imperial Valley

The origins of Boulder Dam lay in a privately-financed project to irrigate Southern California's Imperial Valley. As conceived by the Colorado Development Company in the late 1890s, this scheme diverted water from the Colorado river for use on a huge tract of desert land just north of the California/Mexico border. Much of this land lies below sea level which makes it relatively easy for water to flow to the valley. At the same time, this distinctive topographical condition also makes the valley susceptible to flooding. In the 1850s, the Anglo-American pioneer Oliver Wozencroft first appreciated the agricultural possibilities afforded by the topography of the lower Colorado River delta. He realized that an ancient channel of the river (long-since filled in with silt) had once carried fresh water directly into what was termed the "Colorado Desert." And there was no reason why — with a little human assistance — it could not do so again. In the

1890s Wozencroft's idea was picked up by the California Development Company, an enterprise masterminded by Charles Rockwood in partnership with George Chaffey, and marketed as irrigating the "Imperial Valley" rather than the more foreboding Colorado Desert.[1]

Just north of the Mexican border the company "cut" a short canal (about four miles long) connecting the existing riverbed to the ancient channel. Fitted with wooden headgates, this canal provided a relatively inexpensive means for diverting water into the Imperial Valley. In the short term, the company's plans to make the desert bloom proved easy to implement — nature had accomplished most of the "excavation" work hundreds of year earlier — and by 1902 thousands of acres of prime agricultural land was being irrigated. However, a serious problem loomed, relating to the "cut" connecting the Alamo channel and the main Colorado.[2] Demand for water grew, but the Alamo Canal kept clogging with of silt. Silt accumulation proved particularly troublesome in the section of the canal closest to the river and this — in conjunction with a desire to move the headgates beyond U.S. jurisdiction so that irrigation in Mexican territory could also be promoted — prompted the company in 1904 to excavate a larger opening into the river below the U.S./Mexico border. As before, water flow was to be regulated by wooden headgates.[3]

In June 1905 high water washed away these new headgates and an uncontrolled surge roiled into the Imperial Valley. As more water flowed in from the Colorado River, the "new" Alamo River canal deepened and widened. The Southern Pacific Railroad (whose trackage passed through the valley) dumped trainload-after-trainload of rock to close off the canal entrance to little short-term effect. Despite appeals for the federal government to stanch the deluge, President Teddy Roosevelt declined to interfere in what he perceived to comprise the affairs of a private corporation. Eventually flooding was brought under control by the Southern Pacific, but it took almost two years — and an expenditure of 2 million dollars — before the breach was closed. In the meantime, thousands of acres of low lying land were inundated under what came to be known as the Salton Sea. Even today the Salton Sea (which now is primarily fed by subsurface irrigation drainage rather than surface flow) remains an enduring part of the Southern California landscape.[4]

In 1909, the California Development Company entered bankruptcy after transferring most of its assets to the Southern Pacific Railroad; in 1911, landowners north of the international border formed the Imperial Irrigation District and five years later the district purchased the water supply system from the railroad .[5] Once the flooding had been checked, the valley resumed agricultural production, yet fear that an uncontrolled "break" might recur lingered. Soon the district and its boosters began clamoring for federally-supported flood protection and — in the midst of the uncertainty that followed the collapse of the Porfirio Diaz government — for political protection from possible

Mexican interference with the water supply system.

The Fall/Davis Report

Prior to the end of World War I, the Imperial Irrigation District sought assistance from the federal government for excavation of a completely new canal entirely within U. S. territory (designated the "All-American Canal").[6] Following the end of the war, the district also began seeking federal support for construction of a flood control/storage dam somewhere in the lower Colorado River watershed that would protect the Imperial Valley from a recurrence of the disastrous inundation of 1905-07. In holding back flood water, such a dam could also increase water supplies for irrigation in the vast expanse of the greater Imperial Valley. As early as 1902, Arthur Powell Davis (at that time the Assistant Chief Engineer of the Reclamation Service) initiated studies of the resources of the Colorado River.[7] Between 1902 and 1919 the issue of lower Colorado River development was overshadowed by myriad other on-going projects. However, at the end of World War I the Reclamation Service had completed many of the large projects that had occupied its attention during the previous decade (including the Arrowrock Dam in southern Idaho and Elephant Butte Dam in New Mexico) and was looking for new work. In 1915 Davis had become Director of the Reclamation Service and he appreciated that controlling the lower Colorado could involve construction of one of the most prominent water storage structures in the world. In the words of California water historian Norris Hundley:

> "The proposed legislation [for an All-American Canal] immediately caught the eye of Arthur Powell Davis... who saw it as a perfect opportunity to raise anew his dream of harnessing the Colorado River... the canal made sense, concluded Davis, but only if it were part of a larger design. To build such an aqueduct without also constructing dams to control 'the flood menace' would doom the canal to a short life... Davis told all who would listen [that the Imperial Valley problem] 'is inseparably linked with the problem of water storage in the Colorado Basin as a whole.'"[8]

As a result of lobbying on the part of the Imperial Irrigation District and support from Davis, in May 1920 Congress approved a study authorizing the Reclamation Service to develop preliminary plans for an All-American Canal and a Colorado River storage dam.[9] Known as the Kincaid Act (it was sponsored by representative Moses Kincaid of Nebraska, Chairman of the House Committee on Irrigation), this action — which was to be co-financed by the Imperial Irrigation District — represented the beginning of practical planning for the Boulder Dam.[10]

When issued in 1922, the study authorized by the Kincaid Act became known as the Fall/Davis Report (it was officially prepared under the auspices of Secretary of the Interior Albert Fall in concert with Davis). The report established key parameters for what became the Boulder Canyon Act and proposed construction a of large dam that would do much more than simply store floods and protect the Imperial Valley. Most importantly, Davis proposed that hydroelectric power production be considered a key part of the project with construction costs underwritten by the sale of hydroelectric power. From a strictly practical point-of-view, this proposal made sense. There was no question that huge amounts of power could be generated by a dam extending to a height of over 500 feet and holding back more than 20 million acre-feet of water. But from a political perspective, the use of electric power revenues as the primary means of financing the dam was much more problematic because it raised questions as to the proper role of the federal government in generating and selling electricity. The privately-financed electric power industry controlled most of America's electric power grid in the 1920s and opposed legislation that might erode its ability to retain that control. A huge federally-financed dam on the Colorado River paid for by hydroelectric power represented a threat to that control. In the political environment of the pro-business 1920s -- when the Republican Party controlled both the White House and Congress -- the "public power" issue was always controversial in the context of the proposed Boulder Canyon Project. As historian Paul Kleinsorge noted in the 1940s:

> "The controversy over the power aspects of the project, however, was not a dispute that was confined to the relatively local ambitions of [California and Arizona]. It was a clamorous argument that took on the aspects of a nation-wide debate, chiefly because it involved the whole question of whether or not the federal government should enter large-scale power production activities..."[11]

As part of the Fall/Davis Report, Davis took on the task of developing a basic plan for the design and construction of a high dam and hydroelectric power plant in the vicinity of Boulder Canyon. Although the Reclamation Service recognized that there were other possible storage dam sites along the length of the Colorado River (in fact, such sites as Glen Canyon would eventually be developed after World War II) the agency quickly focused on Boulder Canyon because of its large storage capacity and its proximity to prospective water users and electric power consumers in Southern California.[12] Both Boulder Canyon and the nearby Black Canyon (which lay about 20 miles further downstream) offered dramatic, narrow gorges with steep granite walls extending upwards from the riverbed for hundreds of feet. Investigations initially focused on Boulder Canyon (hence the name chosen for the project) but, very early in the process, studies were also carried out at Black Canyon in order to find the best possible site.

Selection of the Black Canyon Site

At the beginning of the Reclamation Service's work it was assumed that the proposed dam would be built in the narrow gorge known as Boulder Canyon. During the early planning stages, attention did not focus so much on a precise location for "Boulder Dam" as it did on the notion that the dam should be built somewhere downstream from the Grand Canyon and in a location that would be relatively accessible to the electric power market of Southern California. Thus, advocacy of a dam at Boulder Canyon was undertaken by the Service in the context that this represented a more desirable alternative than a large storage dam further upstream at Diamond Creek, Bridge Canyon, Glen Canyon or Lee's Ferry.[13]

As early as December 1921 Davis appreciated that it would be desirable to explore the possibility of using a site in Black Canyon as an alternative to Boulder Canyon (where geological testing had been underway since early 1921). In the context of the Colorado river basin they essentially provided the same possibilities of service to southern California interests. Because Black Canyon lay 20 miles further down the river it represented an opportunity to develop a small (yet not insignificant) amount of hydropower that would otherwise be difficult to develop. This factor came to the fore in December 1921 when Davis counseled Weymouth:

> "I am inclined to think it best to make one or more borings at Black Canyon, because a dam at that point would utilize about thirty feet of fall which occurs between that point and our camp at Boulder Canyon, and this fall cannot be utilized in any other way."[14]

At the same time, Black Canyon was not so far downstream that it could not inundate the expansive reservoir site lying upstream from Boulder Canyon; in fact, the latter site could actually provide for greater storage capacity. By the beginning of 1922 the Service was carrying out geological explorations at Black Canyon to discern the quality of bedrock at the site and the depth of excavation that would be required for dam foundations.[15] In July, Weymouth reported to Davis that initial investigation of the upper end of Black Canyon (termed line "A") did not appear promising and he went so far as to state that:

> "The foundation rock at line A in Black Canyon is not suitable for bearing pressures of 40 tons per square foot as used on the granite of Boulder Canyon, [and] the soft and porous structure of some of the rock may render this site entirely unsuitable for such a high dam. In this connection I will say that I am personally very doubtful of the feasibility of a dam 600 feet high in Black Canyon, unless the conditions at the lower site prove to be very much better..."[16]

With this less than encouraging prognostication, studies soon focused on the lower end of Black Canyon (line "D"). As it turned out, conditions at this location proved much better than at the upper end. Following a two-day field visit in November 1922, Davis reported to Weymouth:

> "No one doubts the feasibility of the Black Canyon site. The rock in the bottom of line D is much better than that secured at the head of the canyon last year... I think we should make a choice between Black and Boulder Canyons as soon as possible so as to stop expenditures at the site rejected."[17]

With this endorsement and encouragement, attention shifted to Black Canyon and in early 1924 it was officially recommended as the site of the proposed Boulder Dam. As the Weymouth Report explained the situation:

> "An extensive geological examination has been made... [and while] both dam sites [Boulder and Black Canyons] are excellently adapted to the construction of a very high dam... the granite of Boulder Canyon is superior to the breccia of Black Canyon for carrying great loads... [nonetheless] the investigations led to the adoption of the lower site in Black Canyon for the reason that it is more accessible [for construction equipment and materials]; the maximum depth to bedrock is less than at the upper site in Boulder Canyon and for the same height of dam the reservoir capacity is greater."[18]

Thus, the selection of Black Canyon was not made because it offered better geological conditions (in fact, by this criteria it was judged a bit less desirable than Boulder Canyon). Rather, the Black Canyon site was selected because it would allow for a less costly structure based upon savings in logistical expenses (in terms of excavation and connecting the site to existing transportation networks) and a larger reservoir for a given height of dam.

In this light, it is worth recalling that the initial decision in December 1921 to investigate the Black Canyon site had been rationalized in terms of the additional 30 feet of head available for hydroelectric power production that would otherwise be lost had the dam been built at Boulder Canyon. This rationale was excluded from the recommendation presented in the Weymouth Report, but this omission was likely made been more for political expediency than because the additional 30-foot power drop had somehow been forgotten. Hydroelectric power generation remained at the core of the planning for the "high dam" but -- in light of possible controversy related to "Public Power" development

-- it was often downplayed in the mid-1920s. This is particularly apparent in a description provided to the engineer/author Edward Wegmann in 1927 by the Bureau of Reclamation/Department of the Interior; this description specifically stated that:

> "The primary objects in the construction of this dam are: 1) To permit the use of the normal flow of the Colorado River in the upper Colorado River Basin without injury to prior rights below the reservoir by replacing such diversions from storage. 2) To extend the use of the waters of the Colorado River for irrigation and domestic purposes in and adjacent to the lower Colorado Basin. 3) To provide flood protection for lands along the Colorado River below the reservoir and in the imperial Valley. The accomplishments of these objects requires a reservoir of large capacity and a high dam, presenting attractive possibilities of power development incidental to the use of water for the primary objects of the reservoir."[19]

Thus, the official position was that hydroelectric power production was only "incidental"to the "objects" for building the dam. But this was not reflective of the key role played by hydroelectric power in justifying the financial underpinnings of the dam. As Kleinsorge later observed:

> "The generation of electrical energy was given the last place in the list of purposes of the act [authorizing construction of the dam] and last place in the priority of uses. Yet in spite of this ranking it is one of the most important phases of the project. It is through the sale of electric power that the project is to be made a financially solvent and self-supporting undertaking... The fact remains that no other practical method of financing the project had been suggested and if the project could not have been made self-supporting through the sale of electric power it would not exist today."[20]

Known publicly as the Swing-Johnson Act, the legislation calling for "construction of the All-American Canal and a dam at or near Boulder Canyon... providing for the leasing of the power privileges by the Secretary of the Interior...." was first introduced in Congress in 1922. The first Swing-Johnson Act remained in committee and never came up for a vote; undeterred Congressman Phil Swing and Senator Hiram Johnson resubmitted it three more times over the next six years. By 1928 it called for a dam with a reservoir capacity of at least 26 million acre-feet and the construction of a power plant by the federal government that could then be leased to other organizations (be they public or private) for actual operation and power generation.[21]

By the time the final site location for the lower Colorado storage dam was recommended by the Weymouth Report in 1924, so much effort already had gone into the promotion of a "Boulder Canyon Project" that no effort was made to transform the nomenclature to the "Black Canyon Project" or "Black Dam." The name Boulder Dam remained unchanged until 1930 when it was designated Hoover Dam. Nonetheless, from 1924 on, all work related to Boulder Dam revolved around the lower site (line "D") in Black Canyon and this is where the structure stands today.

The Design of Boulder Dam

During the early planning stages for what became the Boulder Canyon Project, Davis and his staff made an effort to consider a range of possibilities for the design of the big storage dam on the Lower Colorado. Based upon the Service's experiences with the Roosevelt, Elephant Butte, and Arrowrock dams, it is not surprising that a massive concrete/masonry gravity design attracted the interest of Davis, his Chief Engineer Frank Weymouth, Dam Design Engineer John L. Savage, and project engineer Walker Young. At the same time, the Service had experience building massive embankment dams (such as Belle Fourche in South Dakota and Strawberry Valley in Utah) as well as thin arch concrete masonry dams (Pathfinder and Shoshone, both in Wyoming). As it turned out, the decision to utilize a curved gravity concrete design involved some preliminary consideration of alternative designs. However, the selection of a massive curved gravity design came quickly and without laborious review or analysis of alternative designs.

In late 1920 Davis initiated correspondence with Lars Jorgensen, a European-trained engineer who had become a prominent advocate of thin arch dam design (especially constant angle arch dams). Davis wrote to Jorgensen in order to help discern whether or not a storage dam of this type might be feasible to build across the lower Colorado.[22] While previously Davis had been prominently associated with massive gravity dams such as Roosevelt and Arrowrock, he retained an interest in the arch designs and his interaction with Jorgensen testifies to this point.[23] During the next year, the use of a thin arch design (either constant radius or constant angle) officially remained a possibility but little action to forcefully promote such a design is evident in available records.[24]

In contrast, the notion that the Service would rely upon a massive design was publicly expressed by Davis as early as October 1920 (even before he corresponded with Jorgensen) when he wrote the Chief Engineer of the Los Angeles County Flood Control District in response to a "request for some information concerning tentative plans made for a dam in Boulder Canyon." In is response, Davis indicated that "studies have been made for a section of masonry or concrete of the gravity type, and a rock fill and earth section, the latter not being regarded as certainly feasible."[25] In early 1924 Weymouth submitted a "Report on the Problems of the Colorado Basin"-- usually referred as the Weymouth Report -- in which Volume Five focused on "Boulder Canyon: Investigations, Plans and Estimates." In this report, no mention is made of any thin arch designs that may have been considered for the big storage dam. Instead, Weymouth reported only that "studies have been made of rock-fill and concrete dams of various types" and further explained:

> " there is a grave question whether life and property below a dam of such unprecedented height and a reservoir of such enormous capacity should through the construction of a rock fill dam be subjected to a risk which could be removed by the adoption of a concrete dam... With all possible safeguards taken in the construction of a rock-fill of the height proposed it must be admitted that its overtopping would result in certain and sudden destruction with overwhelming disaster in the valley below. The dams adopted are believed to be the safest that can be built — concrete dams of the gravity type built on a curved plan — and estimates prepared indicate that the concrete dams could be built at less cost than rock-fills of the same height." [note: the use of the plural 'dams' in this quotation refers to three designs of various heights — ranging from about 525 feet to over 700 feet — developed for the same site].[26]

In other words, Weymouth's report reveals that, although the Bureau estimated that there existed some possible economic advantages of a massive curved gravity design over a rock-fill structure, concerns over the possibility that a rock-fill design might someday be overtopped comprised a key rationale for selecting a curved gravity design. In fact, Weymouth went so far as to advocate a curved gravity design that would not feature any type of spillway by noting that overtopping could probably be prevented by opening up all possible discharge outlets through the powerhouse and the dam. But even if the flooding overwhelmed the capacity of these discharge outlets, Weymouth counseled that:

> "Any overtopping would be of short duration and the dams have been designed to pass rare floods over the top with safety which can not be done in the case of a rock-fill dam."[27]

Instead of special spillways drilled through the rock abutments, Weymouth proposed that outlet pipes (controlled by huge valves) be built directly into the dam itself. These would be able to draw water from the lower depths of the reservoir and discharge it from the downstream face of the structure. The other — and more advantageous — means of discharging water from the reservoir would be through penstocks drilled through the rock abutment along the Nevada side of the canyon walls; these would feed into a hydroelectric power house about a half mile downstream from the dam where they would deliver water to large-scale turbine/ generator units. In formulating a basic plan for how best to construct the dam, Weymouth also proposed that the same tunnels used to carry water to the powerhouse provide vital service during the construction process. Specifically, they were to be used to divert the flow of the Colorado River around the dam site so that temporary rock-fill cofferdams could protect the site from flooding and allow excavation down to bedrock foundations in the middle of the stream bed.

Thus, by the beginning of 1924 the Weymouth Report laid out the basic features of what would become Boulder Dam. Over the next four years, Weymouth's proposal underwent careful consideration by the Bureau and by 1928 it had undergone significant revision at the hands of J. L. Savage; the most important of these revisions involved:

1) the drilling of diversion tunnels through both the Nevada and Arizona abutments (two tunnels on both sides of the river);

2) the construction of two "glory-hole" spillways that would connect into the diversion tunnels and provide assurance that the dam would never be overtopped;

3) the construction of powerhouses immediately downstream and adjacent to the dam structure on both the Nevada and Arizona sides of Black Canyon that would tap into the diversion tunnels (and to other tunnels connected to outlet towers built directly upstream from the dam).[28]

Clearly, these changes represent important alterations to the Weymouth design and are of central importance in defining the form of the dam/powerhouse/penstock/spillway system as it was actually built. But — beyond the drilling of spillway discharge tunnels to feed into the diversion tunnels — they do not constitute anything that cannot be understood as an evolution of the Weymouth design. And even the addition of spillway tunnels represented an uncomplicated (yet certainly creative) expansion of the diversion tunnel system.

During the mid-1920s, the specific character of the Boulder Dam design continued to evolve as more was learned about geological conditions and as the Bureau became interested in utilizing the "Trial-Load" method of design to confirm the safety of the massive curved gravity design. While the "Trial-Load" method of analysis undoubtedly figured into the final dimensioning of the dam's profile, it did not prompt any dramatic changes or modifications.[29] In fact it is difficult to discern any radical differences between the preliminary profile that accompanied Weymouth's 1924 report and the design as built. Both represent curved gravity designs featuring extremely ample gravity sections and the use of "Trial Load" techniques of analysis did little in terms of altering the basic form of the design. In the same way, research on scale models of the dam also figured into the Bureau's analysis of structural safety and gave them greater confidence in its stability, but it is difficult to perceive how the basic form of the design was altered by such work.[30]

In 1928 -- near the end of the approval process for the Boulder Canyon Project -- Congress authorized the formation of a special "Colorado River Board" separate and distinct from the Bureau's own board of consulting engineers and intended to provide an independent assessment of the proposed dam's safety and feasibility.[31] At the end of the year (just prior to congressional passage of the Boulder Canyon Project Act) the Colorado River Board approved the dam's basic design, but recommended that the maximum allowable stresses in the massive structure be reduced from 40 tons per square foot to 30 tsf. Although this might have appeared to the layperson as a rather simple way to increase the strength of the design, to the Bureau it represented a problem because strict adherence to this requirement would significantly add to the (already massive) bulk of the dam and thus increase its (already expensive) cost. Without overtly resisting this directive, the Bureau nonetheless made no meaningful alteration to the design. Instead, the Bureau opted to claim that more sophisticated mathematical analysis (in line with the "Trial-Load" method) indicated that the proposed design in fact did not exceed a maximum allowable stress of about 34 tons per square foot and this was considered adequate to meet the 30 tons psf criteria; in Mead's words: "It is not believed that the maximum stress as finally calculated will appreciable exceed the 30-ton limit. It is believed that the general plan of the dam will can be agreed upon without serious difficulties."[32] Thus, in essence, the Colorado River Board's recommendation had no substantive effect on the final design.[33]

In his 1928 "Revised Plan" Savage took care not to criticize Weymouth's Report as being somehow faulty and in need of correction. Rather, he simply stated that "The Weymouth plan for the dam and power plant... constitutes a preliminary study on which to base an estimate of cost. The plan was not considered as a final design and should not be considered as such."[34] In this context, it is important to note that the design of Boulder Dam cannot be ascribed to any single individual, but instead represents a collaborative effort that extended over several years time. Davis, Weymouth, and Savage all played important roles in overseeing preparation of the basic design and, in concert with other Service/Bureau staff members, deserve credit as designers of Boulder Dam.[35]

Los Angeles

The preceding discussion has focused on the technical and engineering aspects of the basic dam design. In contrast, the architectural treatment of the dam's surface features was handled in a very different manner and emanated from a source quite distinct from the Bureau's Denver office. During the 1920s the architectural treatment of the dam was assumed to adhere to a neo-classic style featuring design motifs such as eagles with wide-spread wings. In 1931, long after all the major technical issues involving the design had been determined, the Bureau commissioned Los Angeles architect Gordon Kaufmann to develop a more modern appearance for the dam. By simplifying the surface treatment of the design and utilizing a monumental "art deco" style, Kaufmann created an evocative, streamlined facade for the massive structure. While the prominence of the dam in American culture is no doubt tied in part to its modernistic design motif, the circumstance of hiring a non-government architect to carry out this work occurred very late in the design process and was very much separate and distinct from the rest of project.[36]

It is fitting and appropriate that the surface treatment for the Boulder/Hoover Dam emanated from a Los Angeles architect, because in the interim between the initiation of the project by Imperial Valley advocates and its final authorization, the City of Los Angeles and other southern California communities came to play a central and vital role in promoting the Boulder Canyon Project. As early as July 1921 Los Angeles had expressed interest in helping build Boulder Dam in return for control over its hydroelectric power plant.[37] And by 1924 this interest had expanded into a formal water claim being filed on the city's behalf for a flow of 1500 cubic feet per second of the Colorado River's flow.[38] With this claim, the City of Los Angeles served as the catalyst for the Colorado River Aqueduct and for what soon evolved into the Metropolitan Water District of Southern California (MWDSC).

Perhaps most importantly in terms of Congressional approval for the Boulder Canyon Project, the MWDSC was to comprise the most important customer for the power generated at Boulder Dam. As noted in the MWDSC's first annual report:

> "It was early recognized that to secure favorable consideration [by the U.S. Congress, the Boulder Canyon Project] must be self-supporting and that the power to be generated from any development which was built must find a market which would eventually return all costs of the entire project to the Government. As additional engineering work for a Colorado River Aqueduct was done it became evident that any practicable diversion of the river must be done at an elevation lower than that of much of the area to be served, and would involve pumping. Such pumping was practicable only if a large amount of power could be obtained at low price. This created, at once, a potential market for a

> substantial part of the power from any major Colorado River development. When these facts, as well as the need for an additional domestic water supply in Southern California were laid before Congress support for the Swing-Johnson measure became easier to obtain."[39]

In other words, the need to draw huge amounts of electric power to facilitate operation of the Colorado Aqueduct provided a means of assuring hesitant Congressmen that Boulder Dam would not become some kind of white elephant, generating huge quantities of power that no one would want — or pay for. The MWDSC could sign contracts guaranteeing power sales and, in turn, the Federal Government (and Federal taxpayers) could rest assured that such contracts would be honored because the MWDSC possessed the right to directly tax land within its service area. In 1930, when Secretary of the Interior Ray Lyman Wilbur authorized 50-year leases that governed use of Boulder Dam power for 50 years, over 64% of the dam's power was reserved for use in Southern California: 36% went to the Metropolitan Water District of Southern California to pump water through the Colorado Aqueduct, a little more than 9% to the Southern California Edison Company (and other private power companies) and about 18% to the City of Los Angeles and other municipally-owned utilities in Southern California. Although Arizona and Nevada were each allotted 18% of the dam's power, many years would pass before these states developed markets large enough to utilize their full allotments.[40]

Thus, the primacy of hydroelectric power that energized Davis' initial promotion of the Boulder Canyon site because of its relative proximity to southern California -- as well as the subsequent investigation of the Black Canyon site because it allowed for the capture of a 30-foot water drop that would otherwise be lost for power production purposes -- eventually proved to be key to the dam's legislative and financial success. While the project may have been born out of the flooding of the Imperial Valley by an uncontrolled Colorado River, its long-term viability rested upon the ability of urban interests in greater Los Angeles to absorb its enormous cost -- which was budgeted at a minimum of $165 million in the 1928 Boulder Canyon Project Act.[41]

ENDNOTES:

1. Norris Hundley, *The Great Thirst: Californians and Water*, 1770-1990 (Berkeley: University of California Press, 1993) p. 205; Mildred de Stanley, *The Salton Sea: Yesterday and Today*, pp. 17-24; and Kevin Starr, *Material Dreams: Southern California Through the 1920s* (New York: Oxford University Press, 1990), pp. 20-44. The Colorado River drains over 200,000 square miles of land flowing west and south out of the Rocky Mountains. After crossing the Utah/Arizona border and passing the river crossing point known as Lee's Ferry, the Colorado flows westward through the Grand Canyon. Soon afterwards it reaches the Boulder and Black Canyons that straddle the Arizona/Nevada border. Turning southward once it reaches the vicinity of Las Vegas, Nevada, the Colorado River soon forms the 200-mile long border between the states of California and Arizona. Finally, at a distance more than 1000 miles from its headwaters in Wyoming and Colorado, the Colorado River enters — at least it did prior to the erection of large storage dams — the state of Sonora, Mexico and disperses across an expansive delta to the Gulf of California

2. Starr, *Material Dreams*, pp. 25-29; Beverly Moeller, *Phil Swing and Boulder Dam*, (Berkeley: University of California Press, 1971) p. 5; de Stanley, *The Salton Sea*, pp. 25-27. Economic growth of the valley was rapid and by October 1903 100,000 acres were under cultivation, supporting a population of 4,000.

3. Starr, *Material Dreams*, pp. 34-36..

4. Starr, *Material Dreams*, pp. 38-40; de Stanley, *The Salton Sea*, pp. 33-43.

5. Moeller, *Phil Swing and Boulder Dam*, pp. 10-11.

6. Moeller, *Phil Swing and Boulder Dam*, p. 15.

7. Hundley, *The Great Thirst*, pp. 204, 449-450.

8. Hundley, *The Great Thirst* , p. 207.

9. At first, the Imperial Irrigation District did not embrace Davis' efforts to promote a large-scale storage dam as part of the development of the Lower Colorado River fearing that it might overshadow their efforts to promote an All-American canal, but this reticence dissolved fairly quickly. See Hundley, *The Great Thirst* , pp. 208-209. The possibility of federal involvement in building some type of storage dam across the lower Colorado River was championed by the indefatigable Congressman Phil Swing who had earlier served as lawyer for the Imperial Irrigation District. As a member of the U.S. House of Representatives, throughout the 1920s Swing assumed responsibility for keeping the

All-American Canal/ Boulder Canyon Project in the public eye. Working with his counterpart California Senator Hiram Johnson, Swing kept abreast of all the political nuances related to the Boulder Canyon Project and he made sure that during the 1920s Congress was presented with a series of Swing-Johnson Acts positing federal authorization of the project.

10. Moeller, *Phil Swing and Boulder Dam*, pp. 17-18; Kleinsorge, *Boulder Canyon Project*, p. 76; the cost of planning studies for Boulder Dam eventually came to about $400,000 with approximately $170,000 of this coming from irrigation interests in Southern California.

11. Kleinsorge, *Boulder Canyon Project*, pp. 281-282; also see Jay Brigham, *Empowering the West: Electrical Politics Before FDR* (Lawrence: University Press of Kansas, 1998) for useful background on the debate over public vs. private power in the pre-New Deal Era.

12. See E.C La Rue, *Colorado River and Its Utilization* (Washington D.C.: Government Printing office, 1916), USGS Water Supply Paper No. 395; E.C La Rue, *Water Power and Flood Control of Colorado River Below Green River* (Washington D.C.: Government Printing office, 1925), USGS Water Supply Paper No. 556; and Joseph Stevens, *Hoover Dam: An American Adventure* (Norman: University of Oklahoma Press, 1988), pp. 270. During debates about the project in the mid-1920s, the possibility of building a smaller-scale, less expensive "flood control" dam (usually at a site designated Mohave Valley near the town of Topack, California) was frequently raised because it could be erected without reliance upon hydroelectric power sales. However, this dam would not have allowed for a significant storage of flood waters for irrigation, domestic water supply or power and thus held little appeal except for people interested in essentially blocking the construction of a large-scale dam on the lower Colorado.

13. The desirability of a Boulder Canyon reservoir over one located at Glen Canyon (located upstream from the Grand Canyon) is prominently stressed in A. P. Davis to F. E. Weymouth, December 18, 1921; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, November 1, 1921- December 31, 1923.

14. A. P. Davis to F. E. Weymouth, December 18, 1921; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re: Dams and Reservoirs, November 1, 1921- December 31, 1923.

15. Stevens, *Hoover Dam: An American Adventure*, p. 21 provides a Bureau of Reclamation photograph showing geological test drilling underway in Black Canyon in February 1922.

16. Chief Engineer (F. E. Weymouth) to Director (A. P. Davis), July 7, 1922; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, November 1, 1921- December 31, 1923.

17. A. P. Davis to F. E. Weymouth, November 30, 1922; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, November 1, 1921- December 31, 1923.

18. Bureau of Reclamation, "Report on the Problems of the Colorado River, Volume 5, Boulder Canyon: Investigations, Plans and Estimates," February 1924, p. 3; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 477; Colorado River, Weymouth Report, 1924, part 5.

19. Memorandum from Chief Engineer R. F. Walter to Commissioner Mead, February 21, 1927; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, December 31, 1923 - 1929.

20. Kleinsorge, *Boulder Canyon Project* , pp. 83-84.

21. Kleinsorge, *Boulder Canyon Project* , p. 78.

22. See Lars Jorgensen to A. P. Davis, December 15, 1920; A. P. Davis to Lars Jorgensen, December 23, 1920; Lars Jorgensen to A. P. Davis, December 29, 1920; and A. P. Davis to Lars Jorgensen, January 10, 1921; all in National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, 1920 - November 1, 1921.

23. For evidence of Davis's early interest in Jorgensen's design work see the file on "Yuba Dam" (later called Spaulding Dam) built by the Pacific Gas and Electric Company in northern California in 1912-13 in the, John R. Freeman Papers, MIT Archives and Special Collections, Cambridge Massachusetts.

24. See index attached to F. E. Weymouth (Chief Engineer) to Director (A. P. Davis), December 2, 1921; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, November 1, 1921 - December 31, 1923

25. A. P. Davis to J. W. Reagan, October 5, 1920; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and

Reservoirs, 1920 - November 1, 1921.

26. Bureau of Reclamation, “Report on the Problems of the Colorado River, Volume 5, Boulder Canyon: Investigations, Plans and Estimates,” February 1924, p. 4; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 477; Colorado River, Weymouth Report, 1924, part 5.

27. Bureau of Reclamation, “Report on the Problems of the Colorado River, Volume 5, Boulder Canyon: Investigations, Plans and Estimates,” February 1924, p. 6; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 477; Colorado River, Weymouth Report, 1924, part 5.

28. J. L. Savage, “Revised Plan for Boulder Canyon Dam and Power Plant: Memorandum to Colorado River Board,” November 24. 1928; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 492; Folder 301.1, Colorado River Project.

29. For early confirmation on how the “Trial-Load” method was used to justify the final design see Elwood Mead, “Memorandum to the Secretary re the Meeting of the Consulting Engineers to Approve Detail Plans of Boulder Dam,” Dec. 28, 1929; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Board & Engineering Reports on Construction Features, 1929. Also see U.S. Department of the Interior, *Boulder Canyon Project Final Reports, Part IV - Design and Construction* (Denver: Bureau of Reclamation, 1941), pp. 25-28.

30. Model tests are noted in U.S. Department of the Interior, *Boulder Canyon Project Final Reports, Part IV - Design and Construction* (Denver: Bureau of Reclamation, 1941), pp. 28-29.

31. The Colorado River Board was authorized in May 1928 as Congress debated the fourth Swing-Johnson Act. Concern over the safety of the proposed Boulder Dam was heightened by the failure of the Los Angeles’ St. Francis Dam in March 1928 which killed approximately 400 people; the Colorado River Board was apparently intended to help assuage fears that a similar fate might befall Boulder Dam. See Moeller, *Phil Swing and Boulder Dam*, pp. 11, 114-115, 118.

32. The manner in which the design could be considered as meeting the 30 tons psf criteria are described in Elwood Mead, “Memorandum to the Secretary re the Meeting of the Consulting Engineers to Approve Detail Plans of Boulder Dam,” Dec. 28, 1929; National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Board & Engineering Reports on Construction Features, 1929.

33. The acceptance by the Colorado River Board of the Bureau’s rationale for not revising the design in accord with their earlier recommendation is acknowledged in U.S. Department of the

Interior, *Boulder Canyon Project Final Reports, Part IV - Design and Construction* (Denver: Bureau of Reclamation, 1941), pp. 25.

34. J. L. Savage, “Revised Plan for Boulder Canyon Dam and Power Plant: Memorandum to Colorado River Board,” November 24. 1928, p. 1; National Archives, Denver; *Records of the Bureau of the Reclamation*, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 492; Folder 301.1, Colorado River Project.

35. In correspondence with Edward Wegmann concerning how design of the proposed Boulder Dam should be credited, it was reported that it “was first proposed in the Denver Office of the Bureau of Reclamation Mem. A.S.C.E, under the supervision of Mr. J. L. Savage. Mem. A.S.C.E (Designing Engineer, Bureau of Reclamation) and subsequently modified in minor particulars by Consulting Engineer A. J. Wiley Mem. A.S.C.E, of Boise Idaho, and L.C. Hill, Mem. A.S.C.E, of Los Angeles, California.” Significantly, both Davis and Weymouth — who were unquestionably involved in the evolution of the Boulder Dam Design — were both no longer employees of the Bureau or the federal government at the time (1927) when this letter was written and perhaps were excluded simply for this reason. See Chief Engineer (R. J. Walter) to Commissioner (Elwood Mead) Feb. 21, 1927, National Archives, Denver; Records of the Bureau of the Reclamation, RG 115; General Administration and Project Records, Project Files, 1919-45; Entry 7; Box 490; Folder 301.1, Colorado River Project, Correspondence re Dams and Reservoirs, Dec 31, 1923-1929.

36. The best discussion of Kaufmann’s work in developing the architectural form of the dam is in Richard Guy Wilson, “Machine Age Iconography in the West,” *Pacific Historical Review 54* (1985) pp. 463-493. Interestingly, after undertaking a considerable amount of research into the subject, Wilson was obliged to report that: “Why Kaufmann was selected [as architect] remains unknown.” (p. 476).

37. Moeller, *Phil Swing and Boulder Dam*, p. 24.

38. Charles A. Bissell, *The Metropolitan Water District of Southern California: History and First Annual Report* (Los Angeles: Metropolitan Water District of Southern California, 1939) p. 36.

39. Bissell, *The Metropolitan Water District of Southern California*, p. 38-39

40. A good review and analysis of the Boulder/Hoover Dam power contracts is provided in Kleinsorge, *Boulder Canyon Project* , pp. 146-166.

41. Kleinsorge, *Boulder Canyon Project* , pp. 138-140, provides analysis of the cost of the Boulder Canyon Project Act which indicates that more than $206 million would ultimately be due the Federal Government in repayment.