PROCEEDINGS • TWENTIETH ANNUAL CONFERENCE

Association of State Floodplain Managers

COAST TO COAST

20 YEARS OF PROGRESS

JUNE 10-14, 1996 • SAN DIEGO, CALIFORNIA

Drainage Master Planning for the Largest Irrigation District in the United States

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INTRODUCTION

Within southeastern California's Imperial Valley lies an area that has one of the highest agricultural production rates in the world (see Figure 1). This arid region generates this level of production as a result of year-round growing conditions and an extensive network of irrigation canals operated by the Imperial Irrigation District (IID). In concert with the canal system, the IID maintains a corresponding network of "drains," 1,430 miles of open channels (and some pipes) that were primarily designed to convey surface and tile drain runoff from irrigation of the cultivated fields. The drains discharge into the region's two major rivers (the New and Alamo rivers) and drainage sink (Salton Sea). To the extent that the individual drains have capacity, they also convey stormwater runoff.

With the North American Free Trade Agreement (NAFTA) and the expanding role of cross-border trade, the farming towns that dot the valley have grown at record rates in response to industrial, commercial, and residential needs. Considering the need for proactive stormwater management in conjunction with this development, IID initiated the preparation of a PDMP spanning both the IID service area and the surrounding tributary drainage basin. In addition to describing drainage basin characteristics and unique aspects of the IID drains, this paper

The authors thank the IID for the support of this project and for permission to publish this paper.

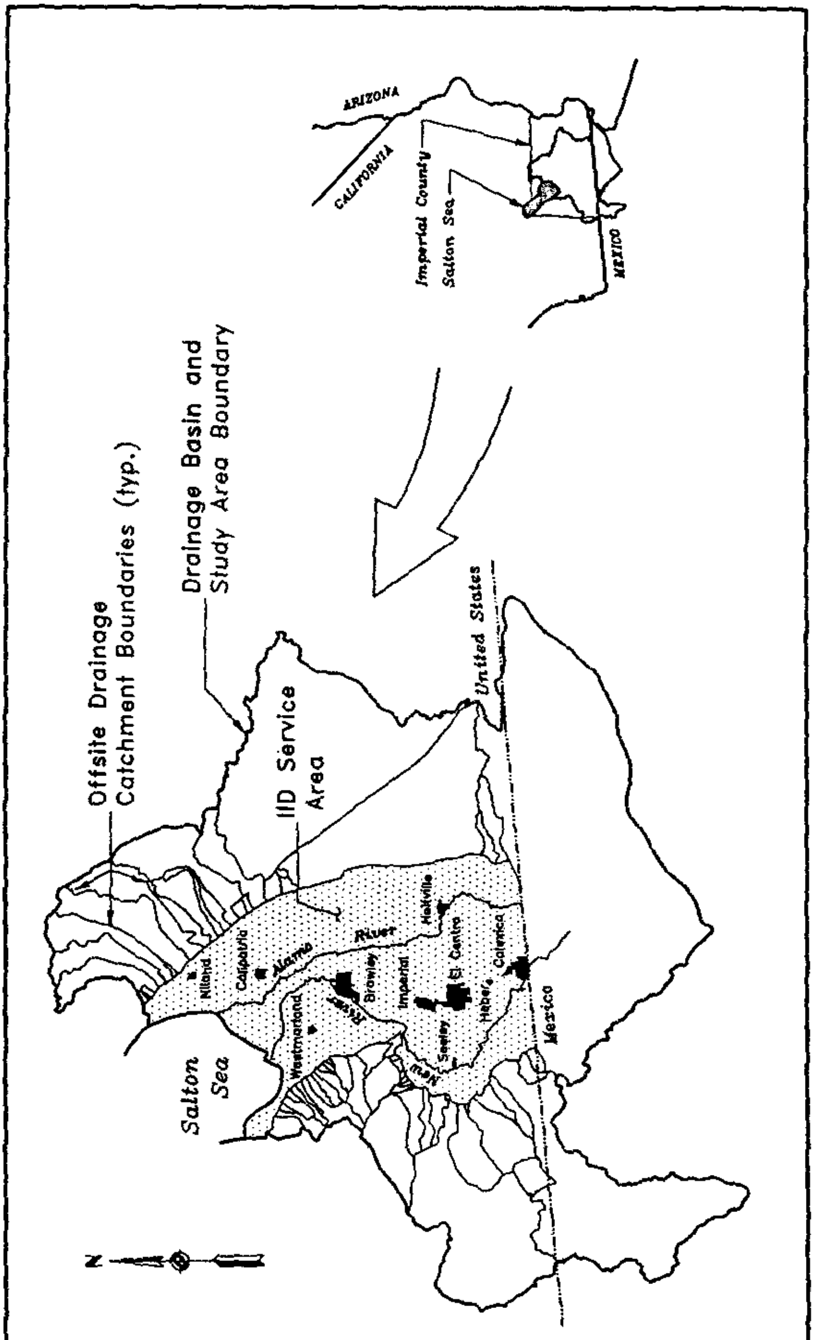

Figure 1. Imperial Valley drainage basin.

presents the approach and results of the PDMP, including initial concepts for improving the drains to provide prescribed levels of flood protection.

DRAINAGE BASIN CHARACTERISTICS

The Imperial Valley is located within the southern portion of the larger Salton Sea basin, which encompasses approximately 3,380 square miles. The central portion of the drainage basin is characterized by very flat terrain. Within the central area of the basin is the 860-square mile area that is irrigated by IID (IID service area) and is home to several urban centers and scattered clusters of individual homes. Surrounding the central area of the basin are expanses of largely undeveloped terrain that include sparsely vegetated desert, sand dunes, and steep, rocky mountains. Drainage from the mountainous areas flows into broad alluvial washes that impinge on the perimeter of the IID service area. The 61 "offsite" catchments range from 170 acres to 260 square miles.

The IID drains are interconnected into 160 individual drainage "systems," where each system is a separate watershed that has one discharge point to a river or the Salton Sea. The earthen drains vary from small trapezoidal channels at the upstream ends (as small as 10 square feet), to large multi-channel cross-sections with total areas on the order of 1,000 square feet at the downstream ends. A typical drain has a trapezoidal cross-section with 1.25H:1V side slopes, a 3-foot bottom width and an 8-foot depth. Invert slopes of the drains are typically flatter than the prevailing slopes of the land surface. The average invert slope of the drains is approximately 0.15%, versus an average land surface slope of approximately 0.55%.

At frequent intervals along nearly every drain, crossings for county or farm access roads have been constructed. A typical crossing consist of a single 12-inch to 24-inch diameter pipe in the bottom of the channel and earth fill. This creates a unique drainage system because of its capacity for storing large volumes of flow within the conveyance system. Whereas storage in a typical piped drainage system is often small enough to be ignored, the analysis of this system required particular attention to this storage component. In essence, the existing drain system can be characterized as a series of detention basins connected by small diameter inlet and outlet pipes.

HYDROLOGIC AND HYDRAULIC ANALYSES

The hydrologic analysis procedures and criteria described in the Imperial Valley Hydrology Manual (see Knell et al., 1996) were utilized to develop estimated runoff volumes and peak flow rates. Hydraulic analyses were performed to determine the capacity of the existing system in terms of required and available storage and flow rate. Offsite catchments were analyzed for peak flow rate and runoff volume at the point where the drainage path intersects the perimeter of the IID service area.

A more detailed analysis was utilized to evaluate improvement needs for each drain system within the IID service area. The watershed for each drain system was segregated into subbasins down to the cell level. The concentration point of each cell was represented by a node located along the respective drain. Cells (nodes) were interconnected in a link-node system where each of the 1,630 links are described by detailed drain system data provided by IID. Peak flow rates and runoff volumes were determined at each node.

MASTER PLANNING PARAMETERS

IID staff worked with the Drainage Committee of the IID Board of Directors to assess the relationship between improvement costs and three important parameters: design storm levels, level of confidence in the hydrologic analyses, and the use of floodplain management. These efforts lead to selection of the parameters described below.

Design Storm Level

The design storm level defines the magnitude of the peak runoff quantities that are to be used for analyzing the existing storm drainage facilities and sizing potential improvements. Two storm levels were selected to determine peak runoff quantities: a 2-year design storm for the agricultural areas within the IID service area and all areas outside IID, and a 25-year design storm for the urban areas within the IID service area.

Level of Confidence

Hydrologic analysis involves the application of statistical methods to rainfall data in order to develop estimates of various return frequency storms. The level of confidence is a measure of the statistical reliability of the results of these analyses. Different agencies select different levels. For example, the Federal Emergency Management Agency (FEMA) uses the 50% confidence level in defining its floodplain maps. Local agencies often select higher levels because they are involved in the design and construction of flood control facilities. An 85% confidence level was selected for the IID PDMP (see also Knell et al., 1996).

Floodplain Management

Floodplain management is an approach that can be utilized to reduce the size of a drainage system by detaining some of the runoff in a distributed fashion throughout the catchment before it enters the drainage system. By reducing peak runoff quantities, this approach can lead to a reduction in the size of the drainage conveyance facilities, and a concomitant reduction in capital facility and improvement costs. IID policy currently allows each quarter-section field (160 acres) to have at most one 12-inch diameter tailwater outlet to discharge surface runoff. One application of floodplain management would be to use berms around each field such that storm flows are detained and only allowed to discharge via the single 12-inch outlet. These berms already exist around many of the fields, although some berms may not withstand the pressure of ponded stormwater runoff. Estimates were made to determine the influence of various degrees of on-farm floodplain management on runoff volumes and improvement costs. Different runoff curve numbers (CN) in the hydrologic analyses were used to represent the degree of floodplain management. The construction of berms around each field is not presently required by any regulatory policy, and it was the opinion of the Board Drainage Committee that instituting such a policy could be a burden on the agricultural industry. Based on the perspective that existing berms will provide some measure of floodplain management, the analysis approach selected for the PDMP assumed that one-quarter of the design storm runoff would be detained on the fields.

FLOOD CONTROL IMPROVEMENT CONCEPTS

To accommodate runoff from the offsite areas, earth embankment levees along the perimeter of the IID service area were selected because of their simplicity and low cost. The levees would be constructed with locally available materials, sized for 2-year storm runoff detention, and include emergency spillways sized for 100-year flow rates. For the drains within the IID service area, two approaches were evaluated. Each approach is described below.

Free-Flowing System Approach

All drains would be sized to convey the peak design storm flow and all constrictions in the drains would be removed. Peak runoff flow rates were compared to the existing conveyance capacity to determine the deficiency in terms of cross-sectional flow area. The improvement for a particular drain segment (link) is the volume of excavation necessary to provide conveyance. Road crossings would be replaced by various structures depending on size and site-specific requirements: larger pipe culverts, reinforced concrete box culverts, or bridges. For each link, the existing drain geometry and an estimated number of road crossings formed the basis for estimates of construction costs for installing free-flowing road crossings.

Total Storage System Approach

All the drains would be sized to store all the runoff from the design storm and all existing road crossings remain in place. Runoff volumes were compared to the existing storage capacity to determine the deficiency in terms of channel volume. The analysis was performed on a link-by-link basis such that all runoff would be contained in the drain segment into which it discharges. The volume deficiency was computed for each link, and the improvement for each link was the volume of excavation necessary to provide total storage.

CONCLUSIONS

The IID PDMP provides an initial evaluation of the hydrologic and hydraulic characteristics of the drainage systems within and tributary to the Imperial Valley area, and provides estimated costs for improving these systems to provide the selected levels of flood protection. The results indicate that the total storage approach is least costly in terms of construction cost, with an average cost of about $165 per acre (based on 500,000 irrigated acres within the IID service area). Future elements of IID's stormwater management plan include extending the PDMP efforts to more detailed investigations aimed at developing "drain-specific" improvements. Future improvements may entail combinations of the free-flowing and storage-based approaches depending upon actual conditions along each drain.

REFERENCES

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