# PREDICTION OF SEDIMENT TRANSPORT RATE IN IRRIGATION CANALS USING MODIFIED LAURSEN METHODOLOGY

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## ABSTRACT

An improved method for predicting sediment transport in alluvial channels has been developed based upon modifications of the Laursen (1958) equation and based upon a wide range of field data. The applicability of this new method was tested for irrigation canals. The following canals were selected for the study: ACOP in Pakistan, American canals, Canal del Dique, CHOP in West Pakistan, India canals, and the Rio Grande Conveyance Canal, which have a range of flow depth from 0.67 m to 5.13 m and width from 3.19 m to 140.21 m. Comparisons between computed results from the modified formula and field data verify that the new method can be utilized to compute total bed-material load in canals.

## INTRODUCTION

Many researchers have observed that more than one value of sediment transport can be obtained from the same values of Q, u, $S_w$, $S_f$, and $\tau$, Simons and Senturk (1992) and Yang (1996). Gilbert (1914) first reported the phenomena that different values of transport can occur for the same hydraulic parameters. He concluded that there was no correlation at all between water discharge and sediment discharge. Accordingly, the validity of the assumption that total sediment discharge for a given particle size could be determined by the proposed parameters was questionable. Yang (1996) stated that stream power $\tau u$, identified as the independent variable, has a strong correlation with bed material transport. Lane (1955) and Bagnold (1966) first proposed this concept that stream power has a strong correlation with sediment discharge. Furthermore, Yang (1996) suggested that unit stream power uS has a stronger relationship to bed material transport than stream power. Other researchers suggested that the stream power-type relationships could be utilized in straight channels as well as channels that

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are in the process of changing their patterns from straight to meandering or braiding (Yang, 1977 and 1996; Vanoni, 1978; Yang and Molinas, 1982). It is important to note that in dimensionless form, use of the unit stream power $uS/\omega$, further improved the correlation with bed material discharge (Yang and Kong, 1991). Simons and Senturk (1992) reported that channel gradient is a variable difficult to measure precisely. They suggested that the stream power parameter could be improved by inclusion of a velocity parameter to replace the slope of the channel.

Kodoatie (1999) developed an improved methodology for predicting sediment transport in alluvial channels based upon utilization of a wide range of recirculating flume and field data. A total of 4,532 data sets from 33 river systems as well as 919 data sets from flume studies were utilized to develop a new sediment transport relation to estimate total bed material transport based upon modification of the Laursen (1958) method. Kodoatie adopted the Laursen methodology for analysis because this methodology was expressed in terms that permitted identification and separation of the various parameters, which are generally considered to cover the important variables, related to bed-material transport. .The Laursen equation is:

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d}\right)^{7/6} \left(\frac{\tau_o'}{\tau_{ci}} - 1\right) f\left(\frac{u_*}{\omega_i}\right) \tag{1}$$

The river data utilized by Kodoatie was compiled by the following individuals: (1) Brownlie (1981) and Posada (1995) for the Mississippi, the Amazon, the Orinoco, and the Apure River Systems; (2) Williams and Rosgen (1989) for the Black, the Chippewa, the Chulitna, the North Fork Toutle, the Susitna, the Toutle, the Wisconsin, and the Yampa River Systems; and (3) Long and Liang (1995) for the Yellow and the Yangtze River Systems. Brownlie (1981) and Willcock and Southhard (1988) compiled the laboratory data utilized. The sets of field data were divided into two categories: Group 1 for developing the new proposed equations, and Group 2 for verification and validation. To develop these groups, the river data sets were divided into two groups in random order. Based on sediment size four river data sets were analyzed, including gravel-bed rivers, medium to very coarse sand-bed rivers, very fine to fine sand-bed rivers, and silt-bed rivers. The data were also divided according to the size of river in terms of width and depth. This division was based as follows:

1. small rivers with widths equal to or less than 10 m and depths equal to or less than 1 m,
2. intermediate rivers with widths greater than 10 m and widths equal to or less than 50 m and depths greater than 1 m and equal to or less than 3 m, and
3. large rivers with widths greater than 50 m and depths greater than 3 m.

## MODIFICATIONS OF LAURSEN'S GRAPH

Madden (1985), utilizing Arkansas River data, modified Laursen's concepts. The modification by Madden permitted the analysis of bed material transport by size fractions. The Corps of Engineers' Waterways Experiment Station (1988) adopted this methodology for computing the transport in rivers with a mixture of sand and gravel forming the bed. Madden's modification to Laursen's methodology was based on three sets of special measurements made in the Arkansas River. The first two sets were gathered near Dardanelle in June and July 1957 and in April 1958. The third set was gathered near Morrilton in April 1958. Madden utilized the Missouri River data collected by Bondurant (1958) to validate the rating curves for the Arkansas River. The data sets resulted in best-fit curves that were parallel, but the two data sets did not overlap. The reader is reminded that the two sets of data were from two different rivers and even though they were sand-bed rivers, the methodologies produced by Bondurant and Madden were developed for specific rivers and are not generally applicable to other river systems. An adjustment factor related to the Froude number was utilized to modify the original Laursen equation by Madden (1985) as follows:

$$C_t = \sum_i p_b \left(\frac{d_i}{d}\right)^{7/6} \left(\frac{\tau_o'}{\tau_{ci}} - 1\right) f\left(\frac{u_*}{\omega_i}\right) \left(\frac{0.1616}{F_r^{0.904}}\right) \tag{2}$$

In addition, Copeland and Thomas (1989) proposed a modification of Laursen's (1958) concept. This methodology was formulated to be utilized in both sand-bed rivers and, to a lesser degree, in larger gravel-bed rivers. The modified Laursen equation as presented by Copeland (1989) is:

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d}\right)^{7/6} \left(\frac{\tau_o'}{\tau_{ci}} - 1\right) f\left(\frac{u'_*}{\omega_i}\right) \tag{3}$$

Copeland and Thomas' modification to the Laursen concepts as applied shows their results in Fig. 1.

Kodoatie (1999) modified the Laursen graph using field data as illustrated in Fig. 2. At an earlier date, Bondurant (1958) proposed a modification of Laursen's concepts. Bondurant developed a relationship between ($u_*/\omega$) and f($u_*/\omega$) in the Laursen graph from Missouri River data at Omaha and at Kansas City. At the lower portion of Laursen graph, Bondurant's (1958) modification fits quite well. However, between the upper portion and the lower part of the relation, the values of $u_*/\omega_i$ for the Missouri River data deviate sharply from those of the Laursen graph.

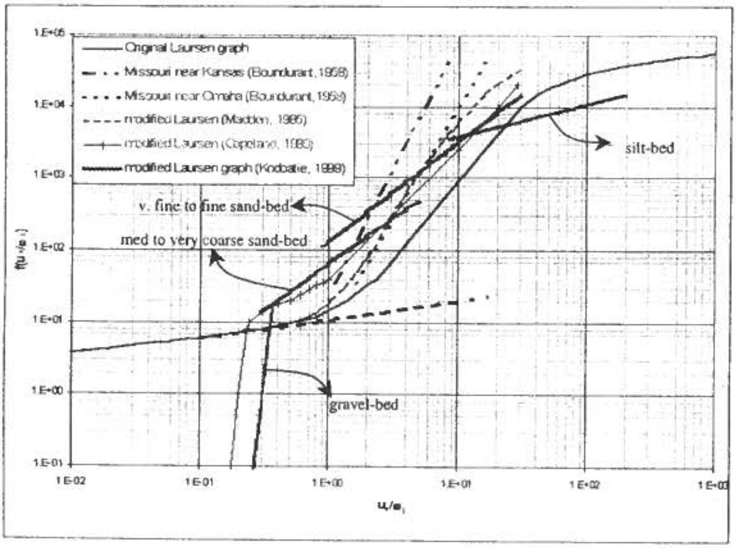


Fig. 1. Modifications of Laursen's (1958) Graph.

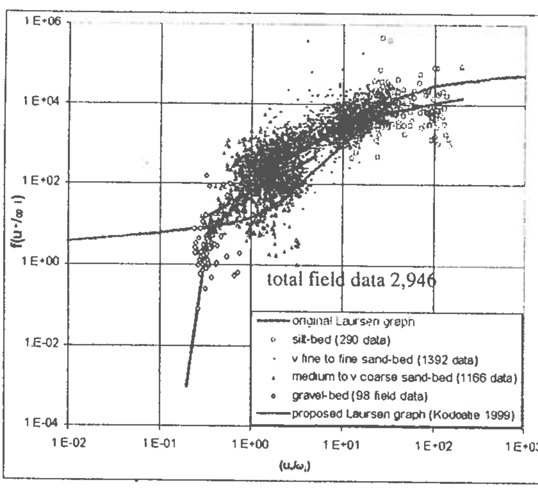


Fig. 2. Original Laursen and modified Laursen graphs by Kodoatie.

## KODOATIE'S MODIFICATION OF THE LAURSEN METHODOLOGY

Kodoatie (1999) utilized a total number of data points (1,459) that pertained to transport of bed material. These data covered the range of particle size from gravels, medium to coarse sand, very fine to fine sand, and silt beds utilized only the dimensionless unit stream power uS/ω. Kodoatie verified that this parameter has a stronger correlation with bed material discharge than other stream power parameters. Figure 3a illustrates the scatter when stream power is plotted against measured concentration of suspended sediment. Figure 3b illustrates the scatter when unit stream power is correlated with measured concentration of suspended sediment. In both of these figures, there is significant scatter. In particular, the data points for gravel-bed rivers plot significantly above the data points for sand-bed and silt-bed rivers. Figure 3c verifies a much stronger relationship between measured concentration of suspended sediment and dimensionless stream power uS/ω. Additionally, the gravel-bed data commingles with the other data.

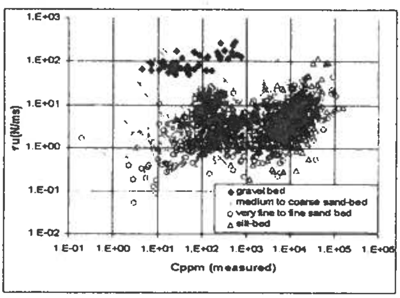


Fig. 3a. Stream Power τu

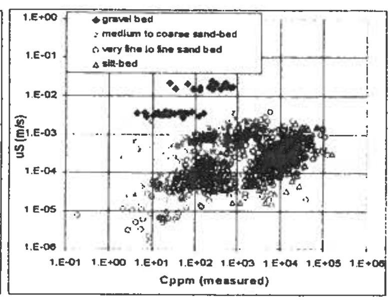


Fig. 3b. Unit Stream Power uS

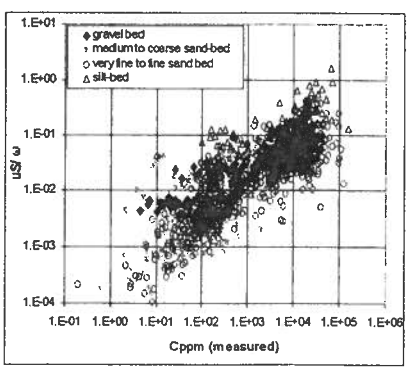


Fig. 3c. Dimensionless Unit Stream Power uS/ω

Fig.3. Relations Among $C_{ppm}$ (Measured), Stream Power, Unit Stream Power, and Dimensionless Unit Stream Power.

Summarizing the three figures, significant variation in these relationships still exists. For the bed material ranging in size from fine to coarse sand, it is difficult to ascertain differences in bed material transport in the relationship between dimensionless stream power and measured suspended concentration. For example, Fig. 3c indicates the same concentration of measured sediment for fine sand-bed rivers and coarse sand-bed rivers. However, the reduction in diameter from gravel-bed rivers to silt-bed rivers tends to increase measured suspended sediment concentration. The Pearson Correlation Coefficients for the analysis illustrated in Figs. 3a through 3c are presented in Tables 1a, 1b, and 1c, respectively.

Table 1. Pearson Correlation Coefficient between $C_{ppm}$ Measured and $uS/\omega$, uS and $\tau u$ for Various Rivers.

A. Gravel-bed Rivers

| | Measured $C_{ppm}$ | $uS/\omega$ | uS(m/s) | $\tau u$(N/ms) |
|---|---|---|---|---|
| $C_{ppm}$measured | 1 | | | |
| $uS/\omega$ | 0.71 | 1 | | |
| uS(m/s) | 0.69 | 0.95 | 1 | |
| $\tau u$(N/ms) | 0.67 | 0.82 | 0.88 | 1 |

B. Medium to Coarse Sand-bed Rivers

| | Measured $C_{ppm}$ | $uS/\omega$ | uS(m/s) | $\tau u$(N/ms) |
|---|---|---|---|---|
| $C_{ppm}$measured | 1 | | | |
| $uS/\omega$ | 0.58 | 1 | | |
| uS(m/s) | 0.45 | 0.9 | 1 | |
| $\tau u$(N/ms) | 0.33 | 0.23 | 0.29 | 1 |

C. Very Fine to Fine Sand-bed Rivers

| s | Measured $C_{ppm}$ | $uS/\omega$ | uS(m/s) | $\tau u$(N/ms) |
|---|---|---|---|---|
| $C_{ppm}$measured | 1 | | | |
| $uS/\omega$ | 0.74 | 1 | | |
| uS(m/s) | 0.76 | 0.87 | 1 | |
| $\tau u$(N/ms) | 0.18 | 0.40 | 0.46 | 1 |

Table 1, continued

D. Silt-bed Rivers

| | Measured $C_{ppm}$ | uS/ω | uS(m/s) | τu(N/ms) |
|---|---|---|---|---|
| $C_{ppm}$measured | 1 | | | |
| uS/ω | 0.45 | 1 | | |
| uS(m/s) | 0.62 | 0.79 | 1 | |
| τu(N/ms) | 0.30 | 0.74 | 0.78 | 1 |

In summary, the dimensionless unit stream power has the best correlation with measured suspended sediment $C_{ppm}$, see Fig. 3c. The strength of the correlation is exhibited in Fig. 4. This figure illustrates the range of dimensionless unit stream power and dimensionless flow depth compared to measured $C_{ppm}$. The dimensionless unit stream power utilizing regression analysis and nonlinear optimization techniques can add other variables to Equation 4 resulting in:

$$C_t = 0.01\gamma\left(\frac{d_{50}}{d}\right)^{7/6}\left(\frac{\tau_o'}{\tau_{c50}}-1\right)10^{f\left(\frac{u_*}{\omega_{50}}\right)}\left(\frac{uS}{\omega}\right)^{a} \tag{4}$$

where a is a variable related to mean bed material diameter as shown in Table 2.

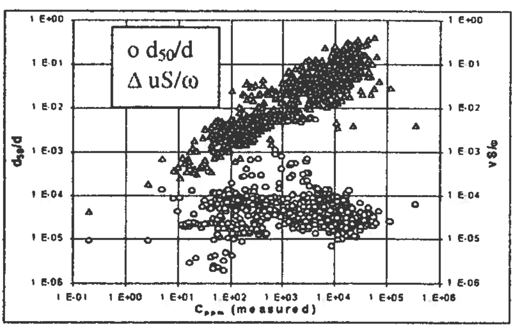


Fig. 4. Range of Dimensionless Unit Stream power and Dimensionless Flow Depth Compared to $C_{ppm}$ Measured.

Equation 4 has been utilized to develop Fig. 5 illustrating the relationship $u_*/\omega$ versus $\log(u_*/\omega)$.

Table 2. Value of "a" in Equation (4) for Various Bed Materials.

| Bed Material | "a" |
|---|---|
| Gravel | 0 |
| Medium to very coarse sand | -0.2 |
| Very fine to fine sand | 0.078 |
| Silt | 0.06 |
| | |

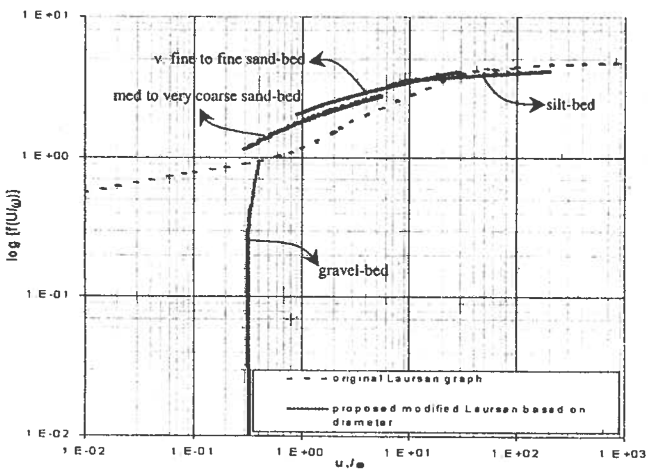


Fig. 5. Proposed Graph by Kodoatie Using Equation (4).

The modified Laursen equation by Copeland was applied by Raphelt (1996) to 10 rivers including: the Toutle, North Fork Toutle, Susitna, Tanana, Oak Creek, Clearwater, Chippewa near Durand, Chippewa near Caryville and Granite Creek Rivers. Utilizing these data, which included 187 sets illustrating conditions in gravel-bed rivers, 147 computed data points were greater than measured values, and 39 data points were within the range of acceptable accuracy, as illustrated by the discrepancy ratio comparing computed measured values. The discrepancy ratio for these data had a range of 0.2 to 5. One set of data points was below an acceptable range of accuracy. Raphelt concluded that the modified Laursen equation by Copeland significantly over-predicted gravel-bed material transport when applied by size fraction. The maximum over prediction was as much as 6,000 times higher than the measured value. The data falling within the range of acceptable accuracy all were for either sand- or very fine gravel-bed streams. The reduction of the critical dimensionless shear stress without taking into account the probability of grains to move and without including a hiding factor are probably the major reasons for over-prediction of bed material transport for those streams with $D_{50} > 4.00$ mm. The modifications to the Laursen equation by Madden, Copeland and Kodoatie are presented in Table 3.

Table 3. Comparison of Modified Laursen Equations

| | | | | | |
|---|---|---|---|---|---|
| 1 | Used the same equation; added adjustment factor related to Froude Number | 1 | Used grain hydraulic roughness instead of grain shear stress | 1 | Used same equation but added dimensionless stream power as the adjustment factor |
| 2 | Used modified graph | 2 | Used modified graph | 2 | Used modified graph; more specific in particle bed diameter from silt to gravel |
| 3 | Used size fraction | 3 | Used size fraction | 3 | Used uniform particle diameter (no fraction) |
| 4 | Used Arkansas River data | 4 | Used both river and flume data (not specified) | 4 | Used 33 river systems and 18 sources of flume data (more than 5,300 total sets) |
| 5 | Graph is higher than original for sand bed; not specified for gravel and silt | 5 | Graph is higher than original for sand bed; for silt not specified; graph for gravel is smaller than new proposed | 5 | Graph is higher than the original for sand bed (sand bed is more specific for very fine to fine sand and medium to very coarse sand); smaller for silt compared to original; graph for gravel is proposed |

## APPLICATION OF THE MODIFIED LAURSEN EQUATION TO TRANSPORT IN CANALS

In order to ascertain the effectiveness of the Kodoatie (1999) equation, it was applied to data sets obtained from irrigation canals. A total of 334 sets of canal data were selected and utilized to test this equation. The data were collected from an array of canals as follows:

- ACOP Canals (West Pakistan)
- CHOP Canals (West Pakistan)
- American Canals (Colorado, Wyoming, Nebraska)
- Canal del Dique
- India Canals
- Rio Grande Conveyance Channel

ACOP Canals

A total of 151 sets of canal data were collected Mahmood, et al. (1979) from five canals in West Pakistan. However, only 142 complete sets of data were utilized in this study.

American Canals

Simons (1957) collected 24 sets of data from canal systems. The canals utilized in Colorado include: Bijou 53 & 54, Fort. Morgan I, II, III; IV, and V; in Wyoming: Laramie I and IV, Garland I and II, Lucerne I and II, North Plate Ditch, the Farmers Canal, In Nebraska: Central Nebraska Public Power & Irrigation and Drainage Canal, Lateral A29.1, the Cozad Canal, the Dawson Canal and the Taylor Canal. Twelve of completed sets of canal data were utilized in this analysis.

Canal del Dique

A total of 61 sets of data were collected in th is canal located in Columbia, South America by Nedeco (1973). Thirty two of these sets of data were utilized in this analysis. The data were collected at 10 stations along this canal.

CHOP Canals

A total of 33 data sets were collected from nine canals in West Pakistan. These data sets were collected by Chaudry, et al (1970) under the auspices of the Canal and Headworks Observation Program (CHOP) of the West Pakistan Water and Power Development Authority, 1962 – 1964, Lahore, West Pakistan.

India Canals

Chitale (1966) collected and reported 32 sets of canals in India.

Rio Grande Conveyance Channel

A total of nine sets of data were collected by Culbertson, et al (1972) at a station called Oak Creek.

The Range of Data Utilized From Canals

The range of data data utilized from canal studies include:

- discharge : 1.15 – 567.00 m3/s
- width : 3.19 – 140.21 m
- depth : 0.67 – 5.13 m
- $D_{50}$ : 0.020 (silt-bed) – 0.715 (sand-bed)
- Slope : 0.000003 – 0.00111

## Analysis of Selected Canal Data

Kodoatie's modification of Laursen's equation was utilized to compare computed results with measured field data. Statistical methods were utilized including the mean discrepancy ratio $\overline{R_D}$ (Bechteller & Vetter, 1989; Nakato, 1990; Yang and Wan, 1991; Hydrau-Tech, Inc., 1998 and Wu, 1999) and the correlation coefficient $C_c$ (Hydrau-Tech, Inc., 1998). The equations for each of these two statistical parameters follow.

$$\overline{R_D} = \sum \frac{R_i}{N}, \qquad R_i = \frac{X_i}{Y_i} \tag{5}$$

$$C_c = \frac{\sum (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum (X_i - \overline{X})^2 \sum (Y_i - \overline{Y})^2}} \tag{6}$$

For perfect correlation, the above statistical parameters utilizing Eq. (5) and Eq. (6) require that $\overline{R_D} = 1$ and $C_c = 1$. The results of the analysis comparing measured $C_{ppm}$ with computed $C_{ppm}$ are shown in Figs. 6a, b, and c. The discrepancy ratio and Pearson correlation coefficients for three ranges of bed-material sizes dictated by the canal data analyzed are illustrated in Table 4. From Fig. 6 and Table 4, it is concluded that the original Laursen equation over-predicts for silt-bed canals, and under-predicts for sand-bed canals. This figure and table illustrate that the comparison of measured concentration with predicted concentration using the Kodoatie modification of Laursen's equation gives much improved results.

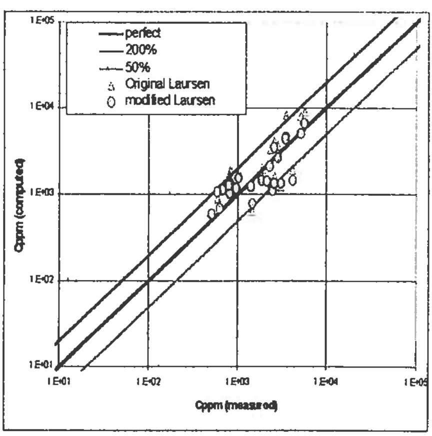


Fig. 6a. Silt-Bed Canals.

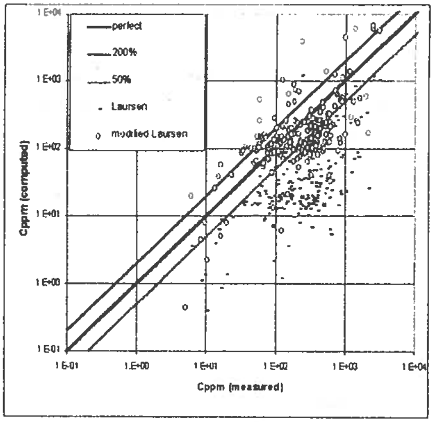


Fig. 6b. Very Fine to Fine Sand-Bed Canals.

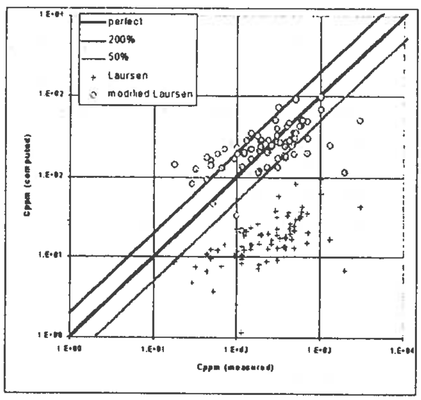


Fig. 6c. Medium to Very Coarse Sand-Bed Canals.

Fig. 6. $C_{ppm}$ Computed and $C_{ppm}$ Measured Data Utilizing Laursen And Modified Laursen.

Table 4. Discrepancy Ratio $\overline{R_D}$ and Pearson Correlation Coefficient $C_c$ Between $C_{ppm}$ Measured and $C_{ppm}$ Measured Using Original Laursen Equation and Modified Laursen Equation

| Type of Canal Bed . | $C_c$ Original | $C_c$ Modified | $\overline{R_D}$ Original | $\overline{R_D}$ Modified |
|---|---|---|---|---|
| Silt | 0.81 | 0.79 | 1.26 | 1.01 |
| Very fine to fine to sand | 0.65 | 0.64 | 0.06 | 1.15 |
| Med. to very coarse sand | 0.41 | 0.41 | 0.09 | 1.27 |

## CONCLUSIONS

The utilization of such an extensive array of data encompassing a wide range of dimensions, gradients, and sizes of bed material has not been accomplished in past research. It is emphasized that:

- The geometry of a canal is selected based upon the type of bed and bank material, flow, variation in flow, and duration of range of flows as dictated by the irrigation/utilities' demand based upon season and climate.

- Unlined canals must be cognizant of the potential for erosion, aggradation and/or deposition.

- The proposed methodology for estimating transport of sediments in erodible canals is considerably improved over existing relationships. However, the transport of sediments in stable alluvial canals is only an improved estimate. In addition, it is recommended that the sorting of sediment through the canal should be done by size fractions to estimate changes in the median diameter of bed material with time and distance.

- Canals may have sediment-laden water and/or clean water at their headworks. If the supply of water and sediment are dependent upon the characteristics of the river, the design, and the operation of the diversion structure, etc., exclusion and ejection structures must be integrated into the design of the headworks.

- It is also concluded that during flood stages in the river the headworks should be closed if at all possible. Otherwise, considerable sediment may be permitted to enter the canal where it will deposit within a short distance of the headworks. This deposition could possibly reduce the capacity of the canal, and, as another alternative, steepen the gradient in a depositional area sufficiently to increase velocities to a level where considerable bank erosion may occur.

## RECOMMENDATIONS

- There is a wide variation in predicted sediment transport in canals. Therefore, sediment exclusion and/or sediment ejection facilities may be required to refine the sediment supply to acceptable limits for a specific canal.

- Regime relations are recommended to estimate channel geometry for canals without linings constructed in erodible soil, Simons and Albertson (1963).

- The regime of the canal may change over time as a consequence of sorting of the natural soil that the canal is constructed within and the introduction of sediments at the headworks from the river into the canal.

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## NOTATION

| | |
|---|---|
| $\rho$ | density of water |
| $\omega$ | fall velocity |
| $\gamma$ | specific weight of water |
| $\tau_{ci}$ | critical shear stress for sediment size $d_i$ |
| $\omega_i$ | fall velocity of the sediment size $d_i$ |
| $\omega i$ | fall velocity of particle dimeter of the $i^{th}$ size |
| $\tau_o$ | shear stress |
| $\tau_o'$ | bed shear stress due to grain size |
| $\tau u$ | stream power |
| $C_c$ | correlation coeficient and is defined by Equation (2.75) |
| $C_i$ | concentration distribution in Equation (2.19) |
| $C_t$ | total average sediment concentration in weight per unit volume |
| d | flow depth |
| $D_{50}$ | mean diameter of sediment |
| $d_i$ | geometric mean diameter of particle of the $i^{th}$ size |
| $F_r$ | Froude number |
| $f\left(\frac{u_*}{\omega_i}\right)$ | functional relation of $u_*/\omega_i$ |

| | |
|---|---|
| $f\left(\frac{u'_*}{\omega_i}\right)$ | functional relation of $u_*'/\omega_i$, Plate 16 Copeland & Thomas (1989) |
| $i$ | data set or point number |
| $N$ | total number of data sets |
| $p_{bi}$ | fraction of bed material of $d_i$ |
| $p_b$ | fraction of bed material |
| $p_i$ | fraction of bed material for diameter particle size $d_i$ |
| $R_i$ | ratio of computed sedimentation and measured sedimentation |
| $\overline{R_D}$ | mean discrepancy ratio |
| $S$ | channel slope |
| $u$ | mean velocity |
| $u_*$ | shear velocity $\sqrt{\tau_o/\rho}$ |
| $u'_*$ | shear velocity due to grain roughness |
| $uS$ | unit stream power |
| $uS/\omega$ | dimensionless unit steam power |
| $X_i$ | computed sedimentation |
| $Y_i$ | measured sedimentation |
| $\overline{X}$ | average of computed concentration of sediment |
| $\overline{Y}$ | average of measured concentration of sediment |

## DETAILS OF CANAL DATA

| Total No | No of Each Canal | Canal Data | Water Discharge $m^3/s$ | Channel Width w m | Flow Depth h m | Flow Velocity v m/s | Mean Bed Diameter $d_s$ mm | W.S Slope $S_w$ m/m | Water Temp °C | Measured Sed Concen C ppm | Bed Form | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 1 | American Canal | 12.59 | 11.73 | 1.83 | 0.59 | 0.096 | 0.000063 | 23 | 370 | 5 | Simons (1957) |
| 2 | 2 | American Canal | 1.56 | 3.49 | 0.80 | 0.56 | 0.173 | 0.000253 | 21 | 249 | 4 | |
| 3 | 3 | American Canal | 1.22 | 3.19 | 0.80 | 0.47 | 0.229 | 0.000294 | 21 | 406 | 3 | |
| 4 | 4 | American Canal | 29.18 | 22.19 | 2.53 | 0.52 | 0.253 | 0.000058 | 22 | 115 | 3 | |
| 5 | 5 | American Canal | 29.40 | 14.81 | 2.59 | 0.77 | 0.311 | 0.000120 | 22 | 185 | 3 | |
| 6 | 6 | American Canal | 4.14 | 9.33 | 1.07 | 0.41 | 0.318 | 0.000135 | 25 | 254 | 3 | |
| 7 | 7 | American Canal | 3.20 | 3.96 | 1.32 | 0.61 | 0.349 | 0.000110 | 26 | 44 | 5 | |
| 8 | 8 | American Canal | 10.47 | 6.92 | 1.60 | 0.95 | 0.360 | 0.000114 | 26 | 131 | 5 | |
| 9 | 9 | American Canal | 6.42 | 12.56 | 1.01 | 0.50 | 0.446 | 0.000218 | 28 | 100 | 3 | |
| 10 | 10 | American Canal | 4.83 | 10.73 | 0.89 | 0.51 | 0.465 | 0.000237 | 26 | 52 | 3 | |
| 11 | 11 | American Canal | 5.01 | 7.62 | 0.89 | 0.74 | 0.580 | 0.000330 | 26 | 448 | 4 | |
| 12 | 12 | American Canal | 5.62 | 7.59 | 1.01 | 0.73 | 0.715 | 0.000302 | 23 | 123 | 4 | |
| 13 | 1 | India Canal | 156.05 | 56.27 | 3.39 | 0.82 | 0.020 | 0.000060 | 20 | 2,601 | 0 | Chitale (1966) |
| 14 | 2 | India Canal | 59.16 | 25.49 | 2.44 | 0.95 | 0.021 | 0.000084 | 20 | 5,759 | 0 | |
| 15 | 3 | India Canal | 153.25 | 56.02 | 3.37 | 0.81 | 0.024 | 0.000060 | 20 | 2,887 | 0 | |
| 16 | 4 | India Canal | 60.72 | 25.56 | 2.49 | 0.95 | 0.025 | 0.000084 | 20 | 5,182 | 0 | |
| 17 | 5 | India Canal | 157.41 | 56.47 | 3.35 | 0.83 | 0.030 | 0.000070 | 20 | 2,316 | 0 | |
| 18 | 6 | India Canal | 68.82 | 25.77 | 2.55 | 1.05 | 0.031 | 0.000110 | 20 | 3,557 | 0 | |
| 19 | 7 | India Canal | 27.67 | 17.98 | 2.52 | 0.61 | 0.033 | 0.000070 | 20 | 831 | 0 | |
| 20 | 8 | India Canal | 68.92 | 25.68 | 2.55 | 1.05 | 0.033 | 0.000110 | 20 | 3,508 | 0 | |
| 21 | 9 | India Canal | 14.11 | 13.49 | 1.85 | 0.57 | 0.036 | 0.000080 | 20 | 1,894 | 0 | |
| 22 | 10 | India Canal | 14.03 | 14.66 | 1.72 | 0.56 | 0.037 | 0.000080 | 20 | 4,230 | 0 | |
| 23 | 11 | India Canal | 27.50 | 17.89 | 2.51 | 0.61 | 0.039 | 0.000070 | 20 | 822 | 0 | |
| 24 | 12 | India Canal | 158.37 | 56.61 | 3.35 | 0.83 | 0.039 | 0.000070 | 20 | 2,175 | 0 | |
| 25 | 13 | India Canal | 2.02 | 5.34 | 0.94 | 0.40 | 0.042 | 0.000115 | 20 | 1,417 | 0 | |
| 26 | 14 | India Canal | 14.81 | 13.55 | 1.86 | 0.59 | 0.043 | 0.000080 | 20 | 2,467 | 0 | |
| 27 | 15 | India Canal | 33.74 | 20.58 | 2.38 | 0.69 | 0.043 | 0.000080 | 20 | 797 | 0 | |
| 28 | 16 | India Canal | 19.45 | 16.03 | 2.38 | 0.51 | 0.044 | 0.000088 | 20 | 624 | 0 | |
| 29 | 17 | India Canal | 3.00 | 5.78 | 1.10 | 0.47 | 0.046 | 0.000115 | 20 | 3,132 | 0 | |
| 30 | 18 | India Canal | 24.59 | 18.07 | 2.24 | 0.61 | 0.046 | 0.000120 | 20 | 2,517 | 0 | |
| 31 | 19 | India Canal | 1.15 | 4.35 | 0.67 | 0.39 | 0.048 | 0.000145 | 20 | 1,031 | 0 | |
| 32 | 20 | India Canal | 19.22 | 15.95 | 2.37 | 0.51 | 0.048 | 0.000088 | 20 | 512 | 0 | |
| 33 | 21 | India Canal | 13.41 | 10.58 | 1.97 | 0.65 | 0.050 | 0.000100 | 20 | 981 | 0 | |
| 34 | 22 | India Canal | 27.89 | 18.17 | 2.17 | 0.71 | 0.050 | 0.000112 | 20 | 2,601 | 0 | |
| 35 | 23 | India Canal | 13.19 | 10.70 | 1.94 | 0.64 | 0.051 | 0.000100 | 20 | 671 | 0 | |
| 36 | 24 | India Canal | 15.87 | 17.34 | 1.57 | 0.58 | 0.056 | 0.000120 | 20 | 596 | 0 | |
| 37 | 25 | India Canal | 242.19 | 79.10 | 3.56 | 0.86 | 0.057 | 0.000064 | 20 | 1,490 | 0 | |
| 38 | 26 | India Canal | 1.29 | 4.31 | 0.79 | 0.38 | 0.064 | 0.000165 | 20 | 760 | 0 | |
| 39 | 27 | India Canal | 30.86 | 20.57 | 2.37 | 0.63 | 0.064 | 0.000080 | 20 | 918 | 0 | |
| 40 | 28 | India Canal | 132.80 | 51.90 | 3.29 | 0.78 | 0.064 | 0.000065 | 20 | 1,976 | 0 | |
| 41 | 29 | India Canal | 131.39 | 51.51 | 3.29 | 0.77 | 0.066 | 0.000065 | 20 | 1,593 | 0 | |
| 42 | 30 | India Canal | 15.84 | 17.31 | 1.57 | 0.58 | 0.070 | 0.000120 | 20 | 726 | 0 | |
| 43 | 31 | India Canal | 166.36 | 66.54 | 3.41 | 0.73 | 0.080 | 0.000057 | 20 | 1,425 | 0 | |
| 44 | 32 | India Canal | 163.72 | 66.55 | 3.39 | 0.73 | 0.082 | 0.000057 | 20 | 1,519 | 0 | |
| 45 | 1 | Pakistan Canal | 158.09 | 118.87 | 2.23 | 0.60 | 0.083 | 0.000070 | 28 | 369 | 5 | Mahmood et al (1979) |
| 46 | 2 | Pakistan Canal | 94.27 | 88.39 | 1.46 | 0.73 | 0.084 | 0.000137 | 28 | 190 | 5 | |
| 47 | 3 | Pakistan Canal | 29.59 | 35.66 | 1.68 | 0.49 | 0.085 | 0.000085 | 31 | 103 | 0 | |
| 48 | 4 | Pakistan Canal | 76.94 | 69.49 | 1.83 | 0.61 | 0.108 | 0.000132 | 27 | 125 | 0 | |
| 49 | 5 | Pakistan Canal | 52.13 | 35.66 | 2.29 | 0.64 | 0.110 | 0.000075 | 32 | 156 | 0 | |
| 50 | 6 | Pakistan Canal | 54.14 | 35.36 | 2.26 | 0.68 | 0.112 | 0.000067 | 21 | 61 | 0 | |
| 51 | 7 | Pakistan Canal | 55.16 | 35.97 | 2.23 | 0.69 | 0.112 | 0.000085 | 22 | 289 | 0 | |
| 52 | 8 | Pakistan Canal | 55.64 | 35.66 | 2.35 | 0.66 | 0.113 | 0.000077 | 28 | 511 | 0 | |
| 53 | 9 | Pakistan Canal | 528.68 | 123.44 | 3.72 | 1.15 | 0.113 | 0.000055 | 23 | 95 | 0 | |
| 54 | 10 | Pakistan Canal | 51.42 | 35.66 | 2.32 | 0.62 | 0.114 | 0.000070 | 23 | 76 | 5 | |
| 55 | 11 | Pakistan Canal | 48.62 | 35.66 | 2.32 | 0.59 | 0.116 | 0.000072 | 23 | 32 | 0 | |
| 56 | 12 | Pakistan Canal | 151.24 | 90.22 | 1.89 | 0.89 | 0.116 | 0.000152 | 29 | 188 | 0 | |
| 57 | 13 | Pakistan Canal | 52.41 | 35.66 | 2.53 | 0.58 | 0.117 | 0.000076 | 28 | 128 | 3 | |
| 58 | 14 | Pakistan Canal | 138.04 | 70.41 | 2.41 | 0.81 | 0.118 | 0.000149 | 26 | 563 | 0 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 59 | 15 | Pakistan Canal | 52.27 | 35.36 | 2.26 | 0.66 | 0.121 | 0.000073 | 23 | 58 | 0 |
| 60 | 16 | Pakistan Canal | 58.33 | 35.97 | 2.47 | 0.66 | 0.122 | 0.000087 | 29 | 166 | 0 |
| 61 | 17 | Pakistan Canal | 51.88 | 35.36 | 2.19 | 0.67 | 0.123 | 0.000086 | 17 | 422 | 0 |
| 62 | 18 | Pakistan Canal | 52.47 | 35.36 | 2.29 | 0.65 | 0.123 | 0.000088 | 24 | 869 | 5 |
| 63 | 19 | Pakistan Canal | 54.74 | 35.66 | 2.19 | 0.70 | 0.124 | 0.000089 | 16 | 560 | 0 |
| 64 | 20 | Pakistan Canal | 130.46 | 70.41 | 2.35 | 0.79 | 0.125 | 0.000129 | 25 | 297 | 0 |
| 65 | 21 | Pakistan Canal | 140.14 | 70.10 | 2.35 | 0.85 | 0.126 | 0.000134 | 28 | 564 | 0 |
| 66 | 22 | Pakistan Canal | 61.73 | 35.66 | 2.53 | 0.68 | 0.127 | 0.000074 | 29 | 79 | 0 |
| 67 | 23 | Pakistan Canal | 27.50 | 86.26 | 0.91 | 0.35 | 0.128 | 0.000142 | 18 | 15 | 0 |
| 68 | 24 | Pakistan Canal | 50.60 | 35.66 | 2.23 | 0.64 | 0.128 | 0.000074 | 24 | 54 | 5 |
| 69 | 25 | Pakistan Canal | 54.37 | 35.36 | 2.19 | 0.70 | 0.129 | 0.000085 | 18 | 367 | 0 |
| 70 | 26 | Pakistan Canal | 96.59 | 86.56 | 1.62 | 0.69 | 0.131 | 0.000139 | 26 | 331 | 0 |
| 71 | 27 | Pakistan Canal | 52.92 | 35.36 | 2.16 | 0.69 | 0.132 | 0.000085 | 18 | 153 | 0 |
| 72 | 28 | Pakistan Canal | 137.82 | 69.19 | 2.38 | 0.84 | 0.132 | 0.000133 | 28 | 607 | 0 |
| 73 | 29 | Pakistan Canal | 136.32 | 127.41 | 1.77 | 0.61 | 0.133 | 0.000086 | 28 | 34 | 0 |
| 74 | 30 | Pakistan Canal | 51.90 | 35.66 | 2.19 | 0.66 | 0.136 | 0.000086 | 18 | 386 | 0 |
| 75 | 31 | Pakistan Canal | 56.29 | 35.97 | 2.29 | 0.68 | 0.138 | 0.000076 | 24 | 184 | 0 |
| 76 | 32 | Pakistan Canal | 52.13 | 49.07 | 1.43 | 0.74 | 0.140 | 0.000148 | 31 | 445 | 0 |
| 77 | 33 | Pakistan Canal | 70.40 | 46.63 | 2.16 | 0.70 | 0.142 | 0.000101 | 25 | 346 | 0 |
| 78 | 34 | Pakistan Canal | 74.11 | 46.63 | 2.23 | 0.71 | 0.142 | 0.000116 | 32 | 233 | 0 |
| 79 | 35 | Pakistan Canal | 79.17 | 46.94 | 2.44 | 0.69 | 0.142 | 0.000095 | 21 | 383 | 0 |
| 80 | 36 | Pakistan Canal | 70.42 | 46.63 | 2.19 | 0.69 | 0.143 | 0.000115 | 30 | 82 | 0 |
| 81 | 37 | Pakistan Canal | 56.80 | 46.33 | 1.92 | 0.64 | 0.144 | 0.000109 | 30 | 225 | 0 |
| 82 | 38 | Pakistan Canal | 70.40 | 46.63 | 2.32 | 0.65 | 0.144 | 0.000116 | 29 | 323 | 3 |
| 83 | 39 | Pakistan Canal | 153.82 | 71.63 | 2.35 | 0.91 | 0.144 | 0.000166 | 26 | 584 | 3 |
| 84 | 40 | Pakistan Canal | 73.60 | 46.63 | 2.26 | 0.70 | 0.145 | 0.000111 | 31 | 335 | 0 |
| 85 | 41 | Pakistan Canal | 70.71 | 46.63 | 2.16 | 0.70 | 0.146 | 0.000099 | 25 | 366 | 3 |
| 86 | 42 | Pakistan Canal | 74.30 | 94.79 | 1.49 | 0.52 | 0.146 | 0.000142 | 26 | 77 | 0 |
| 87 | 43 | Pakistan Canal | 49.64 | 46.63 | 1.68 | 0.63 | 0.147 | 0.000110 | 30 | 36 | 0 |
| 88 | 44 | Pakistan Canal | 67.71 | 46.63 | 2.16 | 0.67 | 0.147 | 0.000110 | 36 | 372 | 0 |
| 89 | 45 | Pakistan Canal | 77.28 | 46.63 | 2.26 | 0.73 | 0.147 | 0.000109 | 31 | 577 | 0 |
| 90 | 46 | Pakistan Canal | 97.44 | 70.41 | 2.10 | 0.66 | 0.147 | 0.000134 | 26 | 164 | 0 |
| 91 | 47 | Pakistan Canal | 71.92 | 46.63 | 2.32 | 0.67 | 0.148 | 0.000112 | 28 | 796 | 0 |
| 92 | 48 | Pakistan Canal | 75.86 | 46.63 | 2.32 | 0.70 | 0.148 | 0.000115 | 31 | 351 | 0 |
| 93 | 49 | Pakistan Canal | 90.53 | 88.39 | 1.52 | 0.67 | 0.148 | 0.000137 | 28 | 183 | 0 |
| 94 | 50 | Pakistan Canal | 68.13 | 46.03 | 2.07 | 0.71 | 0.149 | 0.000127 | 21 | 529 | 3 |
| 95 | 51 | Pakistan Canal | 77.11 | 46.33 | 2.26 | 0.74 | 0.149 | 0.000108 | 31 | 289 | 0 |
| 96 | 52 | Pakistan Canal | 78.55 | 46.63 | 2.32 | 0.73 | 0.149 | 0.000107 | 32 | 385 | 3 |
| 97 | 53 | Pakistan Canal | 139.74 | 71.93 | 2.23 | 0.87 | 0.149 | 0.000107 | 25 | 391 | 0 |
| 98 | 54 | Pakistan Canal | 72.66 | 46.63 | 2.32 | 0.67 | 0.150 | 0.000116 | 25 | 142 | 0 |
| 99 | 55 | Pakistan Canal | 65.92 | 46.63 | 2.16 | 0.65 | 0.151 | 0.000107 | 25 | 290 | 3 |
| 100 | 56 | Pakistan Canal | 29.48 | 93.27 | 0.76 | 0.41 | 0.152 | 0.000088 | 17 | 16 | 0 |
| 101 | 57 | Pakistan Canal | 67.11 | 46.94 | 2.13 | 0.67 | 0.152 | 0.000112 | 30 | 54 | 0 |
| 102 | 58 | Pakistan Canal | 68.84 | 47.85 | 2.19 | 0.66 | 0.152 | 0.000148 | 15 | 410 | 3 |
| 103 | 59 | Pakistan Canal | 74.84 | 46.63 | 2.29 | 0.70 | 0.152 | 0.000107 | 28 | 304 | 0 |
| 104 | 60 | Pakistan Canal | 70.03 | 47.24 | 2.16 | 0.68 | 0.153 | 0.000116 | 30 | 48 | 3 |
| 105 | 61 | Pakistan Canal | 28.77 | 85.65 | 0.91 | 0.37 | 0.154 | 0.000124 | 18 | 13 | 0 |
| 106 | 62 | Pakistan Canal | 92.79 | 100.89 | 1.40 | 0.66 | 0.154 | 0.000106 | 27 | 106 | 4 |
| 107 | 63 | Pakistan Canal | 297.16 | 128.32 | 2.56 | 0.90 | 0.154 | 0.000097 | 25 | 2,083 | 0 |
| 108 | 64 | Pakistan Canal | 68.78 | 47.24 | 2.23 | 0.65 | 0.155 | 0.000147 | 16 | 845 | 3 |
| 109 | 65 | Pakistan Canal | 74.22 | 46.63 | 2.29 | 0.70 | 0.155 | 0.000114 | 28 | 333 | 0 |
| 110 | 66 | Pakistan Canal | 63.77 | 47.55 | 2.16 | 0.62 | 0.156 | 0.000150 | 16 | 110 | 0 |
| 111 | 67 | Pakistan Canal | 72.66 | 46.63 | 2.35 | 0.66 | 0.156 | 0.000112 | 29 | 310 | 0 |
| 112 | 68 | Pakistan Canal | 391.06 | 92.05 | 3.66 | 1.16 | 0.157 | 0.000150 | 30 | 342 | 0 |
| 113 | 69 | Pakistan Canal | 67.85 | 46.63 | 2.13 | 0.68 | 0.159 | 0.000124 | 25 | 146 | 0 |
| 114 | 70 | Pakistan Canal | 75.32 | 46.33 | 2.29 | 0.71 | 0.161 | 0.000104 | 28 | 240 | 0 |
| 115 | 71 | Pakistan Canal | 156.48 | 72.24 | 2.41 | 0.90 | 0.161 | 0.000149 | 27 | 228 | 4 |
| 116 | 72 | Pakistan Canal | 169.08 | 72.24 | 2.47 | 0.95 | 0.162 | 0.000121 | 28 | 169 | 0 |
| 117 | 73 | Pakistan Canal | 69.18 | 46.94 | 2.16 | 0.68 | 0.164 | 0.000102 | 25 | 262 | 0 |
| 118 | 74 | Pakistan Canal | 85.29 | 88.39 | 1.46 | 0.66 | 0.164 | 0.000129 | 26 | 132 | 0 |
| 119 | 75 | Pakistan Canal | 169.67 | 70.71 | 1.89 | 1.27 | 0.164 | 0.000134 | 30 | 872 | 0 |
| 120 | 76 | Pakistan Canal | 78.92 | 99.67 | 1.34 | 0.59 | 0.167 | 0.000104 | 26 | 88 | 0 |
| 121 | 77 | Pakistan Canal | 84.02 | 49.38 | 2.16 | 0.79 | 0.167 | 0.000146 | 31 | 56 | 3 |
| 122 | 78 | Pakistan Canal | 98.94 | 86.56 | 1.65 | 0.69 | 0.167 | 0.000127 | 26 | 232 | 0 |
| 123 | 79 | Pakistan Canal | 85.21 | 47.85 | 2.10 | 0.85 | 0.168 | 0.000132 | 21 | 322 | 0 |
| 124 | 80 | Pakistan Canal | 47.83 | 46.33 | 1.80 | 0.57 | 0.169 | 0.000108 | 32 | 215 | 0 |
| 125 | 81 | Pakistan Canal | 321.51 | 119.79 | 3.41 | 0.79 | 0.169 | 0.000088 | 14 | 138 | 0 |
| 126 | 82 | Pakistan Canal | 86.34 | 49.38 | 2.16 | 0.81 | 0.170 | 0.000147 | 29 | 1,007 | 0 |
| 127 | 83 | Pakistan Canal | 412.04 | 111.86 | 3.63 | 1.02 | 0.170 | 0.000119 | 25 | 216 | 0 |
| 128 | 84 | Pakistan Canal | 90.42 | 49.38 | 2.13 | 0.86 | 0.173 | 0.000153 | 21 | 517 | 0 |
| 129 | 85 | Pakistan Canal | 183.83 | 91.14 | 2.19 | 0.92 | 0.173 | 0.000138 | 26 | 373 | 0 |
| 130 | 86 | Pakistan Canal | 153.31 | 70.71 | 2.10 | 1.03 | 0.174 | 0.000135 | 30 | 419 | 4 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 131 | 87 | Pakistan Canal | 87.50 | 49.38 | 2.19 | 0.81 | 0.176 | 0.000144 | 32 | 328 | 0 | |
| 132 | 88 | Pakistan Canal | 291.27 | 128.63 | 2.59 | 0.87 | 0.176 | 0.000100 | 23 | 115 | 0 | |
| 133 | 89 | Pakistan Canal | 44.00 | 48.77 | 1.34 | 0.67 | 0.177 | 0.000145 | 31 | 94 | 0 | |
| 134 | 90 | Pakistan Canal | 80.19 | 49.07 | 2.04 | 0.80 | 0.178 | 0.000148 | 25 | 69 | 3 | |
| 135 | 91 | Pakistan Canal | 83.31 | 49.07 | 2.07 | 0.82 | 0.179 | 0.000145 | 32 | 122 | 0 | |
| 136 | 92 | Pakistan Canal | 110.72 | 71.02 | 2.16 | 0.72 | 0.179 | 0.000137 | 26 | 481 | 0 | |
| 137 | 93 | Pakistan Canal | 166.87 | 90.53 | 1.89 | 0.98 | 0.179 | 0.000113 | 28 | 319 | 0 | |
| 138 | 94 | Pakistan Canal | 81.52 | 49.07 | 2.13 | 0.78 | 0.182 | 0.000152 | 20 | 399 | 0 | |
| 139 | 95 | Pakistan Canal | 380.58 | 101.50 | 2.90 | 1.29 | 0.182 | 0.000105 | 30 | 57 | 0 | |
| 140 | 96 | Pakistan Canal | 89.48 | 49.68 | 2.16 | 0.83 | 0.185 | 0.000154 | 16 | 104 | 0 | |
| 141 | 97 | Pakistan Canal | 86.25 | 49.68 | 2.23 | 0.78 | 0.186 | 0.000154 | 17 | 167 | 3 | |
| 142 | 98 | Pakistan Canal | 297.41 | 129.24 | 2.62 | 0.88 | 0.187 | 0.000098 | 19 | 229 | 0 | |
| 143 | 99 | Pakistan Canal | 79.60 | 50.60 | 2.13 | 0.74 | 0.191 | 0.000154 | 16 | 279 | 0 | |
| 144 | 100 | Pakistan Canal | 99.48 | 86.56 | 1.65 | 0.70 | 0.192 | 0.000129 | 26 | 289 | 0 | |
| 145 | 101 | Pakistan Canal | 75.69 | 49.07 | 2.16 | 0.71 | 0.193 | 0.000148 | 34 | 98 | 0 | |
| 146 | 102 | Pakistan Canal | 68.92 | 124.97 | 1.46 | 0.38 | 0.195 | 0.000045 | 19 | 5 | 0 | |
| 147 | 103 | Pakistan Canal | 224.44 | 120.70 | 2.50 | 0.74 | 0.195 | 0.000082 | 31 | 65 | 0 | |
| 148 | 104 | Pakistan Canal | 404.62 | 114.30 | 3.57 | 0.99 | 0.197 | 0.000119 | 14 | 614 | 0 | |
| 149 | 105 | Pakistan Canal | 146.62 | 126.49 | 1.71 | 0.68 | 0.198 | 0.000087 | 30 | 48 | 0 | |
| 150 | 106 | Pakistan Canal | 486.82 | 123.44 | 4.27 | 0.92 | 0.199 | 0.000103 | 29 | 205 | 3 | |
| 151 | 107 | Pakistan Canal | 357.76 | 111.25 | 3.54 | 0.91 | 0.201 | 0.000125 | 15 | 162 | 0 | |
| 152 | 108 | Pakistan Canal | 417.42 | 112.47 | 3.66 | 1.01 | 0.202 | 0.000117 | 25 | 114 | 0 | |
| 153 | 109 | Pakistan Canal | 451.40 | 121.92 | 4.24 | 0.87 | 0.202 | 0.000098 | 27 | 67 | 0 | |
| 154 | 110 | Pakistan Canal | 349.97 | 112.17 | 3.47 | 0.90 | 0.205 | 0.000112 | 13 | 106 | 0 | |
| 155 | 111 | Pakistan Canal | 233.10 | 140.21 | 2.07 | 0.80 | 0.206 | 0.000098 | 12 | 268 | 5 | |
| 156 | 112 | Pakistan Canal | 86.54 | 49.68 | 2.16 | 0.80 | 0.207 | 0.000154 | 17 | 71 | 3 | |
| 157 | 113 | Pakistan Canal | 441.29 | 120.40 | 4.08 | 0.90 | 0.208 | 0.000093 | 23 | 181 | 0 | |
| 158 | 114 | Pakistan Canal | 428.15 | 114.00 | 3.69 | 1.02 | 0.210 | 0.000122 | 13 | 54 | 0 | |
| 159 | 115 | Pakistan Canal | 71.30 | 46.63 | 2.10 | 0.73 | 0.211 | 0.000104 | 24 | 79 | 3 | |
| 160 | 116 | Pakistan Canal | 414.47 | 111.56 | 3.69 | 1.01 | 0.214 | 0.000121 | 23 | 86 | 0 | |
| 161 | 117 | Pakistan Canal | 412.72 | 118.26 | 3.60 | 0.97 | 0.220 | 0.000121 | 21 | 57 | 0 | |
| 162 | 118 | Pakistan Canal | 395.13 | 113.08 | 3.81 | 0.92 | 0.222 | 0.000061 | 27 | 89 | 0 | |
| 163 | 119 | Pakistan Canal | 179.56 | 124.36 | 2.04 | 0.71 | 0.223 | 0.000112 | 21 | 52 | 0 | |
| 164 | 120 | Pakistan Canal | 222.09 | 128.02 | 2.26 | 0.77 | 0.226 | 0.000104 | 12 | 97 | 0 | |
| 165 | 121 | Pakistan Canal | 349.46 | 111.56 | 3.41 | 0.92 | 0.230 | 0.000121 | 15 | 44 | 3 | |
| 166 | 122 | Pakistan Canal | 412.29 | 118.26 | 3.63 | 0.96 | 0.233 | 0.000120 | 23 | 106 | 0 | |
| 167 | 123 | Pakistan Canal | 371.80 | 113.39 | 3.51 | 0.94 | 0.234 | 0.000120 | 15 | 493 | 0 | |
| 168 | 124 | Pakistan Canal | 110.12 | 125.58 | 1.86 | 0.47 | 0.241 | 0.000086 | 17 | 19 | 0 | |
| 169 | 125 | Pakistan Canal | 393.21 | 111.86 | 3.57 | 0.99 | 0.242 | 0.000121 | 24 | 108 | 0 | |
| 170 | 126 | Pakistan Canal | 342.95 | 110.95 | 3.29 | 0.94 | 0.250 | 0.000119 | 16 | 33 | 0 | |
| 171 | 127 | Pakistan Canal | 346.71 | 110.64 | 3.32 | 0.94 | 0.252 | 0.000123 | 14 | 71 | 0 | |
| 172 | 128 | Pakistan Canal | 423.25 | 118.26 | 3.63 | 0.99 | 0.258 | 0.000121 | 24 | 59 | 4 | |
| 173 | 129 | Pakistan Canal | 363.33 | 128.02 | 2.77 | 1.02 | 0.260 | 0.000093 | 26 | 265 | 0 | |
| 174 | 130 | Pakistan Canal | 375.65 | 125.88 | 3.81 | 0.78 | 0.268 | 0.000116 | -1 | 17 | 0 | |
| 175 | 131 | Pakistan Canal | 362.91 | 120.09 | 3.57 | 0.85 | 0.272 | 0.000112 | 14 | 116 | 0 | |
| 176 | 132 | Pakistan Canal | 207.62 | 126.19 | 2.16 | 0.76 | 0.273 | 0.000099 | 14 | 49 | 0 | |
| 177 | 133 | Pakistan Canal | 363.64 | 110.95 | 3.44 | 0.95 | 0.275 | 0.000120 | 16 | 103 | 0 | |
| 178 | 134 | Pakistan Canal | 392.70 | 119.79 | 3.57 | 0.92 | 0.275 | 0.000112 | 14 | 94 | 0 | |
| 179 | 135 | Pakistan Canal | 387.69 | 122.23 | 3.72 | 0.85 | 0.279 | 0.000107 | 15 | 32 | 0 | |
| 180 | 136 | Pakistan Canal | 394.77 | 117.65 | 3.54 | 0.95 | 0.279 | 0.000113 | 16 | 44 | 0 | |
| 181 | 137 | Pakistan Canal | 337.28 | 116.43 | 3.20 | 0.91 | 0.289 | 0.000112 | 14 | 39 | 0 | |
| 182 | 138 | Pakistan Canal | 279.80 | 135.94 | 2.32 | 0.89 | 0.293 | 0.000112 | 28 | 123 | 4 | |
| 183 | 139 | Pakistan Canal | 355.72 | 116.74 | 3.26 | 0.93 | 0.299 | 0.000109 | 14 | 42 | 3 | |
| 184 | 140 | Pakistan Canal | 267.65 | 117.35 | 2.80 | 0.81 | 0.313 | 0.000112 | 18 | 65 | 3 | |
| 185 | 141 | Pakistan Canal | 388.05 | 121.92 | 3.66 | 0.87 | 0.331 | 0.000108 | -1 | 18 | 0 | |
| 186 | 142 | Pakistan Canal | 481.92 | 123.44 | 4.30 | 0.91 | 0.364 | 0.000079 | 18 | 29 | 0 | |
| 187 | 1 | Rio Grande Conveyance Canal | 36.51 | 27.43 | 0.89 | 1.50 | 0.180 | 0.000520 | 17 | 985 | 5 | Culbertson et al. (1972) |
| 188 | 2 | Rio Grande Conveyance Canal | 35.38 | 22.56 | 1.10 | 1.43 | 0.180 | 0.000660 | 4 | 2,486 | 5 | |
| 189 | 3 | Rio Grande Conveyance Canal | 35.38 | 22.56 | 1.11 | 1.42 | 0.180 | 0.000590 | 3 | 3,049 | 5 | |
| 190 | 4 | Rio Grande Conveyance Canal | 33.68 | 22.56 | 0.89 | 1.67 | 0.200 | 0.000730 | 17 | 1,348 | 4 | |
| 191 | 5 | Rio Grande Conveyance Canal | 25.19 | 22.86 | 1.50 | 0.74 | 0.210 | 0.000650 | 15 | 906 | 3 | |
| 192 | 6 | Rio Grande Conveyance Canal | 36.22 | 21.34 | 1.02 | 1.66 | 0.210 | 0.001110 | 18 | 2,475 | 4 | |
| 193 | 7 | Rio Grande Conveyance Canal | 25.19 | 20.12 | 1.25 | 1.00 | 0.230 | 0.000650 | 15 | 906 | 3 | |
| 194 | 8 | Rio Grande Conveyance Canal | 25.75 | 21.34 | 1.30 | 0.93 | 0.270 | 0.000650 | 15 | 1,025 | 3 | |
| 195 | 9 | Rio Grande Conveyance Canal | 25.75 | 22.86 | 1.37 | 0.82 | 0.280 | 0.000650 | 15 | 1,025 | 3 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 196 | 1 | Canal del Dique | 421.00 | 135.00 | 3.82 | 0.82 | 0.210 | 0.000057 | 30 | 626 | 0 | Nedeco (1973) |
| 197 | 2 | Canal del Dique | 567.00 | 140.00 | 4.60 | 0.88 | 0.210 | 0.000071 | 30 | 590.8 | 0 | |
| 198 | 3 | Canal del Dique | 478.00 | 120.00 | 3.55 | 1.12 | 0.210 | 0.000062 | 30 | 266.6 | 0 | |
| 199 | 4 | Canal del Dique | 83.00 | 108.00 | 2.47 | 0.31 | 0.210 | 0.000026 | 30 | 11.2 | 0 | |
| 200 | 5 | Canal del Dique | 158.00 | 114.00 | 2.65 | 0.52 | 0.210 | 0.000036 | 30 | 120.7 | 0 | |
| 201 | 6 | Canal del Dique | 440.00 | 85.00 | 4.47 | 1.16 | 0.150 | 0.000059 | 30 | 232.7 | 0 | |
| 202 | 7 | Canal del Dique | 544.00 | 84.00 | 5.13 | 1.26 | 0.150 | 0.000089 | 30 | 156.5 | 0 | |
| 203 | 8 | Canal del Dique | 120.00 | 76.00 | 3.54 | 0.45 | 0.150 | 0.000020 | 30 | 10.2 | 0 | |
| 204 | 9 | Canal del Dique | 111.00 | 41.00 | 4.12 | 0.66 | 0.100 | 0.000091 | 30 | 163.5 | 0 | |
| 205 | 10 | Canal del Dique | 142.00 | 36.00 | 3.92 | 1.01 | 0.100 | 0.000068 | 30 | 393.2 | 0 | |
| 206 | 11 | Canal del Dique | 55.00 | 39.00 | 3.08 | 0.46 | 0.100 | 0.000089 | 30 | 23 | 0 | |
| 207 | 12 | Canal del Dique | 57.00 | 31.00 | 3.42 | 0.54 | 0.100 | 0.000020 | 30 | 5.9 | 0 | |
| 208 | 13 | Canal del Dique | 322.00 | 69.00 | 3.78 | 1.23 | 0.120 | 0.000091 | 30 | 328.8 | 0 | |
| 209 | 14 | Canal del Dique | 280.00 | 85.00 | 3.15 | 1.05 | 0.120 | 0.000077 | 30 | 192.8 | 0 | |
| 210 | 15 | Canal del Dique | 370.00 | 88.00 | 3.91 | 1.08 | 0.120 | 0.000089 | 30 | 140.9 | 0 | |
| 211 | 16 | Canal del Dique | 68.00 | 74.00 | 2.16 | 0.43 | 0.120 | 0.000020 | 30 | 9.3 | 0 | |
| 212 | 17 | Canal del Dique | 89.00 | 32.00 | 2.68 | 1.04 | 0.185 | 0.000170 | 30 | 205.4 | 0 | |
| 213 | 18 | Canal del Dique | 126.00 | 34.00 | 2.62 | 1.41 | 0.185 | 0.000150 | 30 | 151.6 | 0 | |
| 214 | 19 | Canal del Dique | 80.00 | 30.00 | 2.57 | 1.04 | 0.185 | 0.000170 | 30 | 261.3 | 0 | |
| 215 | 20 | Canal del Dique | 29.00 | 27.00 | 2.21 | 0.49 | 0.185 | 0.000020 | 30 | 8.3 | 0 | |
| 216 | 21 | Canal del Dique | 169.00 | 95.00 | 2.21 | 0.80 | 0.120 | 0.000051 | 30 | 163 | 0 | |
| 217 | 22 | Canal del Dique | 228.00 | 90.00 | 2.78 | 0.91 | 0.120 | 0.000041 | 30 | 168.7 | 0 | |
| 218 | 23 | Canal del Dique | 215.00 | 100.00 | 2.93 | 0.73 | 0.120 | 0.000047 | 30 | 222.3 | 0 | |
| 219 | 24 | Canal del Dique | 51.00 | 93.00 | 1.80 | 0.30 | 0.120 | 0.000010 | 30 | 2.9 | 0 | |
| 220 | 25 | Canal del Dique | 225.00 | 86.00 | 2.93 | 0.89 | 0.125 | 0.000041 | 30 | 215.8 | 0 | |
| 221 | 26 | Canal del Dique | 38.00 | 77.00 | 2.49 | 0.20 | 0.125 | 0.000003 | 30 | 16.7 | 0 | |
| 222 | 27 | Canal del Dique | 150.00 | 45.00 | 2.62 | 1.27 | 0.125 | 0.000142 | 30 | 215.9 | 0 | |
| 223 | 28 | Canal del Dique | 128.00 | 35.00 | 2.96 | 1.24 | 0.125 | 0.000129 | 30 | 58.3 | 0 | |
| 224 | 29 | Canal del Dique | 153.00 | 41.00 | 2.63 | 1.42 | 0.125 | 0.000177 | 30 | 124.1 | 0 | |
| 225 | 30 | Canal del Dique | 82.00 | 75.00 | 2.08 | 0.53 | 0.125 | 0.000024 | 30 | 148.4 | 0 | |
| 226 | 31 | Canal del Dique | 95.00 | 75.00 | 1.87 | 0.68 | 0.125 | 0.000046 | 30 | 118.9 | 0 | |
| 227 | 32 | Canal del Dique | 81.00 | 78.00 | 1.82 | 0.57 | 0.125 | 0.000035 | 30 | 89.2 | 0 | |
| 228 | 1 | West Pakistan (CHOP) Canal | 172.44 | 112.78 | 1.31 | 1.17 | 0.090 | 0.000194 | 16 | 232 | 0 | Chaudry et al. (1970) |
| 229 | 2 | West Pakistan (CHOP) Canal | 120.91 | 55.47 | 2.44 | 0.89 | 0.100 | 0.000200 | 20 | 181 | 0 | |
| 230 | 3 | West Pakistan (CHOP) Canal | 109.58 | 57.91 | 2.68 | 0.71 | 0.110 | 0.000080 | 24 | 146 | 0 | |
| 231 | 4 | West Pakistan (CHOP) Canal | 233.61 | 118.26 | 2.47 | 0.80 | 0.110 | 0.000214 | 15 | 148 | 0 | |
| 232 | 5 | West Pakistan (CHOP) Canal | 146.68 | 67.67 | 2.68 | 0.81 | 0.120 | 0.000232 | 24 | 473 | 0 | |
| 233 | 6 | West Pakistan (CHOP) Canal | 359.61 | 111.25 | 2.10 | 1.54 | 0.120 | 0.000116 | 23 | 531 | 0 | |
| 234 | 7 | West Pakistan (CHOP) Canal | 362.44 | 99.06 | 3.08 | 1.19 | 0.120 | 0.000118 | 29 | 464 | 0 | |
| 235 | 8 | West Pakistan (CHOP) Canal | 351.12 | 112.17 | 2.13 | 1.47 | 0.130 | 0.000124 | 18 | 706 | 0 | |
| 236 | 9 | West Pakistan (CHOP) Canal | 424.74 | 111.86 | 2.38 | 1.60 | 0.140 | 0.000155 | 19 | 1,153 | 0 | |
| 237 | 10 | West Pakistan (CHOP) Canal | 166.75 | 67.67 | 2.56 | 0.96 | 0.190 | 0.000051 | 27 | 116 | 0 | |
| 238 | 11 | West Pakistan (CHOP) Canal | 27.52 | 23.77 | 1.68 | 0.69 | 0.200 | 0.000086 | 29 | 286 | 0 | |
| 239 | 12 | West Pakistan (CHOP) Canal | 112.41 | 57.30 | 2.32 | 0.85 | 0.200 | 0.000134 | 24 | 595 | 0 | |
| 240 | 13 | West Pakistan (CHOP) Canal | 322.80 | 120.40 | 2.68 | 1.00 | 0.200 | 0.000196 | 22 | 526 | 0 | |
| 241 | 14 | West Pakistan (CHOP) Canal | 362.44 | 118.26 | 2.99 | 1.03 | 0.200 | 0.000161 | 18 | 663 | 0 | |
| 242 | 15 | West Pakistan (CHOP) Canal | 393.59 | 99.67 | 3.38 | 1.17 | 0.200 | 0.000181 | 17 | 299 | 0 | |
| 243 | 16 | West Pakistan (CHOP) Canal | 413.41 | 110.64 | 2.44 | 1.53 | 0.200 | 0.000115 | 18 | 1,297 | 0 | |
| 244 | 17 | West Pakistan (CHOP) Canal | 209.26 | 71.63 | 3.32 | 0.88 | 0.210 | 0.000127 | 22 | 484 | 0 | |
| 245 | 18 | West Pakistan (CHOP) Canal | 328.47 | 97.54 | 3.32 | 1.01 | 0.210 | 0.000188 | 19 | 432 | 0 | |
| 246 | 19 | West Pakistan (CHOP) Canal | 334.13 | 110.34 | 2.47 | 1.23 | 0.210 | 0.000159 | 20 | 428 | 0 | |
| 247 | 20 | West Pakistan (CHOP) Canal | 342.62 | 116.74 | 3.11 | 0.94 | 0.210 | 0.000254 | 22 | 620 | 0 | |
| 248 | 21 | West Pakistan (CHOP) Canal | 376.60 | 115.82 | 2.35 | 1.39 | 0.210 | 0.000141 | 21 | 702 | 0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 249 | 22 | West Pakistan (CHOP) Canal | 427.57 | 121.62 | 3.17 | 1.11 | 0.210 | 0.000202 | 16 | 1,217 | 0 |
| 250 | 23 | West Pakistan (CHOP) Canal | 146.11 | 55.78 | 2.62 | 1.00 | 0.290 | 0.000182 | 27 | 244 | 0 |
| 251 | 24 | West Pakistan (CHOP) Canal | 153.47 | 58.52 | 2.71 | 0.97 | 0.290 | 0.000165 | 24 | 261 | 0 |
| 252 | 25 | West Pakistan (CHOP) Canal | 255.41 | 112.17 | 2.56 | 0.89 | 0.290 | 0.000207 | 12 | 305 | 0 |
| 253 | 26 | West Pakistan (CHOP) Canal | 114.96 | 57.91 | 2.35 | 0.85 | 0.300 | 0.000140 | 17 | 236 | 0 |
| 254 | 27 | West Pakistan (CHOP) Canal | 122.04 | 53.65 | 2.38 | 0.96 | 0.300 | 0.000185 | 11 | 302 | 0 |
| 255 | 28 | West Pakistan (CHOP) Canal | 138.47 | 66.14 | 2.29 | 0.92 | 0.300 | 0.000165 | 15 | 395 | 0 |
| 256 | 29 | West Pakistan (CHOP) Canal | 138.47 | 59.44 | 2.38 | 0.98 | 0.300 | 0.000179 | 11 | 150 | 0 |
| 257 | 30 | West Pakistan (CHOP) Canal | 143.85 | 63.40 | 2.47 | 0.92 | 0.300 | 0.000238 | 23 | 197 | 0 |
| 258 | 31 | West Pakistan (CHOP) Canal | 139.03 | 57.91 | 2.44 | 0.98 | 0.311 | 0.000176 | 22 | 198 | 0 |
| 259 | 32 | West Pakistan (CHOP) Canal | 226.53 | 109.42 | 2.29 | 0.91 | 0.311 | 0.000185 | 19 | 388 | 0 |
| 260 | 33 | West Pakistan (CHOP) Canal | 399.26 | 112.78 | 3.41 | 1.04 | 0.311 | 0.000178 | 17 | 1,317 | 0 |

Note for bed form:

0 Not observed
1 Plane bed without sed. movement
2 Ripples
3 Dunes
4 Transition
5 Plane bed with sediment movement
6 Standing waves
7 Anti dunes
8 Chute - pools