ATTACHMENT 1

HYDROLOGY REPORT

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HYDROLOGY REPORT
Central Maui Landfill
Facilities Project
May 2, 2016,
Revised July 1, 2017

Scope

This report presents an analysis of surface water management features and provisions for drainage at the proposed Central Maui Landfill Facilities Project site. The analytical methods and content meet or exceed requirements of applicable County of Maui Department of Public Works regulations set forth Title MC-15, Subtitle 1, Chapter 4, "Rules for the Design of Storm Drainage Facilities in the County of Maui", dated July 14, 1995.

Project Description and Background

Existing and proposed development conditions are depicted in Figures 1, 2A, 2B, 2C, 2D and 3 of the CML Facilities Project, Preliminary Engineering Report, July 2017 (attached). The project is described in the following paragraphs with a more detailed description in the attached Preliminary Engineering Report.

Figure 1 provides a vicinity map and an overall site plan of the existing permitted CML as well as the 40.8-acre site of the CML Facilities Project. Figure 2A illustrates the proposed grading of the CML Facilities Project site. Figure 2B illustrates the proposed buildings and facilities areas of the CML Facilities Project and the project drainage plan.

The proposed 40.8-acre "L-shaped" Project site will include two wings, herein designated as the "West" and "North" Extension areas, respectively. These areas were part of former agricultural fields 7201 and 7202 of a Hawaiian Commercial and Sugar Company (Lot 2-A-1, owned by Alexander and Baldwin, Inc.). Figures 2C and 2D display cross-sections A-A' and B-B' through the West Extension Area and section C-C' through the North Extension area for existing and proposed development conditions. Cross sections locations are shown on Figure 2A. Site surface and drainage conditions and proposed developed conditions at the site are summarized in the following paragraphs.

Existing Site Drainage Conditions: The proposed CML Facilities Project site is adjacent to the existing CML landfill and located between Kalialinui Gulch to the northeast and Pulehu Road (an existing 40-foot-wide right of way) to the southwest; the West Extension area is crossed by a 50-foot-wide electrical utility line easement near-parallel to, and approximately 120 feet northeast of, Pulehu Road, and a water easement line (W-1) heading from Pulehu Road towards the Haiku ditch in the north-northwest direction.

<u>*Regional natural drainage*</u>: is directed to the northwest, primarily along or near parallel to Kalialinui Gulch, at average gradients on the order of 2.5 $\pm$ 0.5 percent over a distance of 5 miles

roughly centered at the CML site. Additional regional drainage within the Wailiku District is provided by the southwest-northeast trending Waihee, Haiku and Lowrie ditches, of which the Haiku Ditch is the closest to the CML extension site, namely, less than about one half mile north of both proposed West and North Extension areas. Figure A1 (Appendix A of this Report) provides an aerial photograph of the site and regional drainage features to the north (Haiku Ditch) and to the east (Kalialinui Gulch).

Existing Site Drainage: As shown in Figure A2 (Appendix A), the highest ground surface elevations currently range from approximate 270 feet above mean sea level (MSL), decreasing to approximately 205 feet to the northwest (West Extension), and to 196 feet to the north and northeast (North Extension), with maximum overland flow length of nearly 1720', 1200' and 770' towards the northwest, north and northeast, respectively. The northern portion of the North Extension Area is adjacent to the Kalialinui Gulch, which drains to the northwest.

Natural Slope Gradients: are locally no steeper than about 16 percent around the site's highest elevations, gradually decreasing towards the northwest, north and northeast, with corresponding natural drainage flow directions mostly towards Haiku Ditch. The northern portion of the North Extension Area is adjacent to the Kalialinui Gulch, a natural drainage feature that in turn drains to the northwest.

Three current drainage sub-areas are defined, which are listed as "West, Center and North", respectively, in Summary Table 1 of this report and Figure A2 (Appendix A). Drainage is mostly of shallow-channel type, with average drainage subarea gradients of 3.8, 5.5 and 5.7% for the west, central and northern portion of the CML Facilities Project site, respectively. Maximum lengths of overland flow, elevations, and average gradients are included in Summary Table 1 (Part 1 – Existing Conditions) of this report, and are also approximately depicted in Cross Sections A-A', B-B' and C-C', respectively.

Current Land Use: Sugar cane roads/trails cross the site and adjacent areas extending to the north up to the Haiku Ditch, and to the northwest towards Kalialinui Gulch as shown in site aerial photograph in Figure A1 (Appendix A). Drainage of the West and North Extension Areas is mostly of shallow-channel type, as shown on Figure A2 (Appendix A).

Current Watershed Characteristics and Run-off Conditions: Based on County of Maui Rules for the design of storm drainage facilities, we estimate: a) Infiltration to be "slow"; b) Relief to be "flat" to "rolling"; c) vegetel cover to be "poor" (<10%); and d) existing development type to be "agricultural" for these drainage sub-areas, as listed in Summary Table 1 (Part 1 – Existing Conditions).

Proposed Development:

The proposed West Extension Area will include several new facilities, located as shown on Figure A3, (Appendix A), which are listed below:

- An infiltration basin (Basin A) with a "net" storage capacity (i.e., after deducting a 1 foot freeboard) of approximately 11,581 cubic yards, or about 7.18 acre-foot;
- Abandoned Vehicles Area (2 acres);
- Office Structure: 8,000 square feet (sf);

- Construction and Demolition (C&D) Material Recovery Area: 4 acres, including a 40,000 sf open processing area;
- Metals Processing and Recovery Facility: 8.2 acres, including a 40,000 sf roofed processing facility building;
- Household Hazardous Waste (HHW) and Electronic Waste Collection and Storage Area: 2.4 acres, including a 20,000 sf roofed building;
- Water tank at the highest (southernmost) site location; and
- Access roads and parking stalls for truck-type vehicles, with site Entrances 1 and 2 from Pulehu Road, as shown on Figure A3, (Appendix A).

The North Extension Area will include the proposed new facilities:

- Infiltration basin (Basin B): with a net storage capacity of nearly 15,109 cy, or about 9.37 acre-foot;
- Maintenance Facilities: 3 acres, including a 12,000 sf shop and office building and refuse collection truck parking area;
- Passenger car parking area; and
- Warehouse and Storage Area: 1.4 acres, with a 20,000 sf warehouse building.

Earthwork: The earthwork for the entire site (West and North Extension areas) to accommodate the proposed development as shown on Figure A3 (Appendix A), will be essentially balanced with excavation quantity of 198,000 cy (plus approximately 2,000 of road base and footing excavation) and fill quantity of 200,000 cy.

Proposed West and North Extension Drainage Facilities: Runoff from the proposed CML Facilities Project West and North Extension areas is generally of shallow-channel flow type, to be collected in perimeter asphaltic concrete (AC) paved road, drainage ditches and adjacent AC berms and discharged into the two proposed basins (Basin "A" and Basin "B") located as shown in Figure A3 (Appendix A).

Within the West Extension Area, the AC drainage ditch and berm at this perimeter road is to collect and convey surface runoff water to culvert crossing under the road and then into Infiltration Basin "A". In addition, Infiltration Basin "A" will include an emergency spillway (weir type, 400 feet long) along its outer side (towards the north) in case design peak flows were exceeded during the life of this structure. A rip-rap revetment will be used for erosion control over the outer slope of this emergency spillway, as shown in Detail 1 of Figure 2B (Preliminary Engineering Report). The drainage ditch will be about 12 inches deep, and the AC berm about 8 inches high, as shown in Detail 2 of Figure 2B.

Basins "A" and "B" have net capacities (after deducting their one-foot freeboard) of approximately 11,581 and 15,109 cubic yards (cy), or about 7.18 and 9.37 acre-foot, respectively. Stormwater collected in the proposed basins is to discharge primarily by infiltration through the fractured bedrock in which these basins are constructed.

Within the North Extension area, the proposed Basin "B" will be connected to the adjacent existing CML Phase IV basin, as shown on Figure 2B. Stormwater collected in the existing CML Phase IV basin is discharged primarily by infiltration through the fractured bedrock in which the basin is constructed. It is anticipated that the proposed Basin "B" will function similarly and infiltrate into the bedrock as a primary means of discharge. In turn, if the Basin "B" design storage capacity were exceeded in the event of a major storm, overflow of the combined Basin "B" and Phase IV basin would be conveyed into the adjacent Kalialinui Gulch from the existing Phase IV basin spillway.

Proposed Development Watershed Characteristics and Run-off Conditions: Based on County of Maui Rules for the design of storm drainage facilities, we estimate: a) Infiltration to be "negligible"; b) Relief to be "flat"; c) vegetal cover to be "poor"; and d) proposed development type to be "industrial" to business, for two drainage sub-areas, as also listed in the lower half of Summary Table 1 (Part 2 – Developed Conditions).

HYDROLOGIC RUNOFF COMPUTATIONS

Consistent with the County drainage regulations, the design runoff quantity (peak flow rate, Q) is based on the rational method formula:

Q = CIA where Q: flow, cubic feet/second (cfs)
C: runoff coefficient, dimensionless
I: rainfall intensity, inches per hour
A: drainage area

The rational method formula variables are evaluated as follows.

Drainage Area

For existing conditions: This proposed CML Facilities Project site was subdivided into three drainage subareas, named West, Central and North, with 18.01, 14.32 and 6.47 acres, respectively, as shown in Figure A2 (Appendix A),

For developed conditions: This area was subdivided into two drainage subareas, named West and North, with 28.19 and 10.64 acres, respectively, as shown in Figure A3 (Appendix A).

Design Storm

For existing conditions: a design storm of 1 hour duration and a recurrence interval of 10 years; from County of Maui (CM) Plate 4 in Appendix A, the applicable one-hour rainfall amount for the Puunene area is 2.0 inches; and

For developed conditions: a design storm of 1 hour duration and a recurrence interval of 50 years; From CM Plate 7 in Appendix A, the applicable one-hour rainfall amount for the Puunene area is 2.5 inches.

Run-off Coefficient (C)

For existing conditions: This area was subdivided into three drainage subareas, named West, Central and West, as indicated in Summary Table 1, and Figure A2 (Appendix A) of this report. From CM Tables 1 and 2, the following watershed and drainage area characteristics were selected in estimating run-off coefficients.

- Infiltration: 0.14 (slow);
- Slopes: 0.02 (flat to rolling);
- Vegetal Cover: 0.05 (poor); and
- Development type: 0.15 (agricultural)
- *Runoff coefficient*: C = 0.36, based on the sum of the four above-listed watershed factors.

For developed conditions: This area was subdivided into two drainage subareas, named West and North, as indicated in Summary Table 1, and Figure A3 (Appendix A) of this report.

- Infiltration: 0.20 (negligible);
- Slopes: 0.00 (flat);
- Vegetal Cover: 0.05 (poor); and
- Development type: 0.55 (industrial, business)
- *Runoff coefficient*: C = 0.80, based on the sum of these four watershed factors.

Time of concentration (T_c)

Based on a conservative analysis of existing conditions at the site, using CM Plate 1 (built-up areas), and CM Plate 3 (small agricultural areas) in Appendix A.

For existing conditions: conservatively assuming poor-grass surfaces, for runoff directed to the west, northwest (center) and north, the time of concentration for runoff to reach the perimeters of the site is calculated using CM Plate 1 in Appendix A. Based on flow lengths of 1,718', 1,200', and 770', and average slopes of 3.8%, 5.5% and 5.7%, respectively, the resulting T_c values are as follows:

- West Drainage Subarea ≈ 25 minutes
- Central Drainage Subarea ≈ 19 minutes; and
- North Drainage Subarea ≈ 17.5 minutes;

For developed conditions: assuming bare-soil surfaces, for runoff directed to the west, and north, the time of concentration for runoff to reach the Basins "A" and "B", is calculated using Plate 1 in Appendix A. Based on flow lengths on the order of 500' and 1,313', and average slopes of 2.4% and 2.5%, respectively, the resulting T_c values are as follows:

- West Drainage Subarea ≈ 17 minutes; and
- North Drainage Subareas ≈ 25 minutes (central and west sub-areas).

Rainfall Intensity (I): Based on CM Plate 2 in Appendix A.

For existing conditions: Based on the 1-hour rainfall of 2.0 inches and T_c value of 25, 19, and 17.5 minutes, the charted intensity is 3.0, 3.4 and 3.7 inches per hour, for the existing west, center and north drainage sub-areas, respectively.

For developed conditions: Based on the 1-hour rainfall of 2.5 inches and T_c value of 17 and 25 minutes, the charted intensity is 4.3 and 3.7 inches per hour, for the developed west and north site drainage sub-areas, respectively.

Design Peak Flows, Q: Based on the above-listed values they are conservatively calculated as:

For existing conditions:
$C \approx 0.36$
$I \approx 3.0$ to 3.7 inches/hour = 8.5×10^{-5} ft/sec
$A \approx 39$ acres = 1.70×10^{6} ft^2
$Q \approx CIA \approx C (I_1 \times A_1 + I_2 \times A_2 + I_3 \times A_3) \approx 19.6 + 18.2 + 8.9 \approx 46.7$ cfs, as shown in Summary Table 1 (Part 1 – Existing Conditions) of this report.

For developed conditions:
$C \approx 0.80$
$I \approx 3.7$ to 4.3 inches/hour = 8.5 to 9.3×10^{-5} ft/sec
$A \approx 39$ acres = 1.70×10^{6} ft^2
$Q \approx CIA \approx C (I_1 \times A_1 + I_2 \times A_2) \approx 97.8 + 32.9 \approx 130.7$ cfs, as shown in Summary Table 1 (Part 2 – Developed Conditions) of this report.

Perimeter AC Road/Ditches

The majority of runoff for the developed condition of the West Extension Area will reach the perimeter road/drainage ditch along the north side, which slopes from approximate elevation 238 to 216 feet toward the infiltration basin "A" at longitudinal gradients ranging from approximately 0.5 to 1.8 percent, increasing to the northwest. A trapezoidal shape, AC ditch with a bottom width of 5 feet and a depth of 12 inches below adjacent ground, combined with an 8-inch high AC berm, can convey the maximum expected runoff to the West Basin at approximate elevation 216 feet.

Gradient, i (%)	Velocity, V (feet/s)	Flow Rate, Q (cfs)
0.5	4.2	76.4
1.0	5.9	108
1.5	7.2	132
2.0	8.4	152

Infiltration Basin Storage Capacity Verification – Developed Conditions

Calculations of required basin capacity were made assuming approximate near-parabolic hydrograph peaks. The average storage capacities needed, $C \approx 2/3\ Q \times \Delta t$, are summarized below:

> <u>*Infiltration Basin "A"*</u> (1-hour rainfall, 50-year return period)
> Peak Run-off Flow Rate, $Q \approx 97.8$ cfs;
> $C \approx 2/3 \times 97.8\ ft^3/s \times 3{,}600s \approx 235{,}000\ ft^3$, or
> $C \approx 8{,}737$ cy; and
> Available Net Storage Volume ≈ 11,581 c.y. > 8,737 c.y. (satisfactory)
>
> <u>*Infiltration Basin "B"*</u> (1-hour rainfall, 50-year return period)
> Peak Run-off Flow Rate, $Q \approx 32.9$ cfs;
> $C \approx 2/3 \times 32.9\ ft^3/s \times 3{,}600s \approx 78{,}881\ ft^3$, or
> $C \approx 2{,}921$ cy; and
> Available Net Storage Volume ≈ 15,109 c.y. > 2,921 c.y. (satisfactory).

It should be noted that the calculated basin net storage capacities already exclude the minimum 1-foot freeboard required by the County of Maui Rules. In addition, Basins "A" and "B" will include a 400-foot- and a 120-foot-long spillway (weir type), respectively. The Basin "A" weir spilling over to the north to adjacent sugar cane fields, and the Basin "B" towards the existing adjacent CML Phase IV stormwater basin, which in turn spills over to the Kulialinui Gulch to the north (if its design capacity were exceeded). Therefore, silts will be retained, while cleaner water will spill over during the design rainstorm event. Further, these basins are actually "infiltration" ponds, with bottoms excavated in fractured rock, namely, permeable material.

CONCLUSION

The perimeter AC drainage ditches and infiltration basins designed for the proposed West and North Extension areas are adequately sized to manage the peak runoff from the proposed CML Facilities Project at final development.

Respectfully Submitted,

M. Ali Mehrazarin, P.E.
Principal Engineer

Summary Table 1: Design of Storm Drainage Facilities
Per County of Maui Department of Public Works and Waste Management Rules

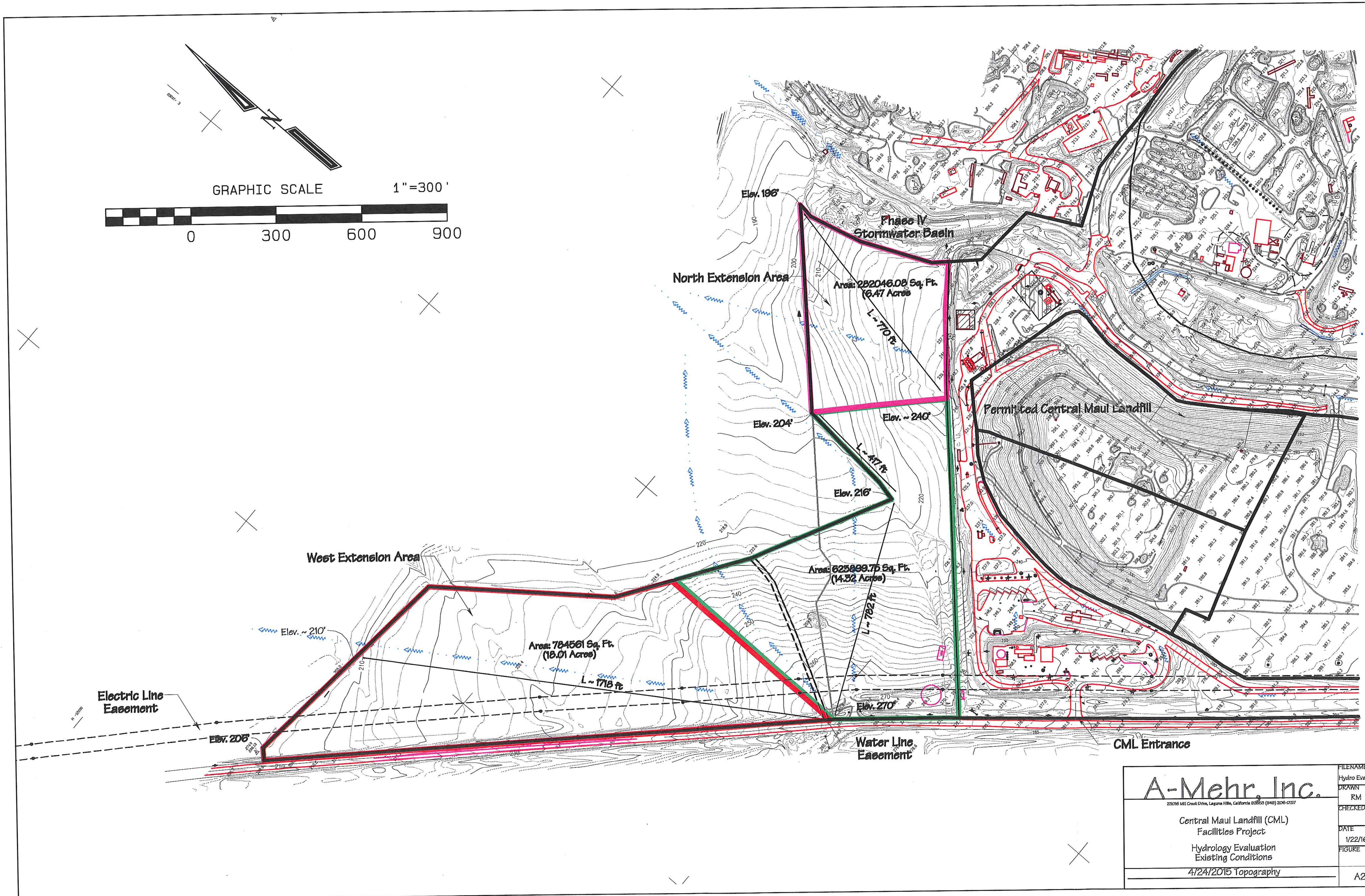
Part 1 - Existing Conditions

Drainage Facilities	West Drainage	Center Drainage	North Drainage	Remarks
On-Site Drainage Area, A_d (sq ft) =	784,561	623,779	281,833	
On-Site Drainage Area, A_d (acres) =	18.01	14.32	6.47	Total Drainage Area = 38.8 acres - From Figures 2 and A1 (Appendix A), this report.
Hydrologic Criteria (§15-04-05)				
1.0 Recurrence Interval, Tm (years)	10	10	10	A_d < 100 acres without sump: Tm ≈ 10 year based on 1-hour storm, per §15-04-05 (a).
1.1 - Run-Off Quantity				Per Rational Method of drainage areas of 100 acres or less, Q = CIA based on accompanying tables and charts.
Watershed/Run-off Coefficient, C				Based on CM Tables 1 or 2, whichever is higher.
Infiltration, C_1	0.14	0.14	0.14	Slow infiltration
Relief, C_2	0.02	0.03	0.03	Flat to rolling (5 to 6%)
Vegetal Cover, C_3	0.05	0.05	0.05	Poor (<10%)
Development Type, C_4	0.15	0.15	0.15	Agricultural (see aerial photo in Figure 4, this report)
$C = \Sigma (C_1 \text{ to } C_4)$	0.36	0.37	0.37	*Built-Up Areas (From CM Table 1)*
Typical for Type of Drainage Area	0.22	0.22	0.22	*Lawns - Heavy soil, average slope 2 to 7% (From CM Table 2)*
Highest Run-Off Coefficient	**0.36**	**0.37**	**0.37**	From CM Tables 1 and 2
Highest Elevation (feet MSL)	270	270	240	From existing ground surface contours (Figures 2 and A1 (Appendix A), this report)
Lowest Elevation (feet MSL)	205	204	196	From existing ground surface contours (Figures 2 and A1 (Appendix A), this report)
Overland Flow Maximum Length, L (feet)	1718	1,199	770	From Figure A1 (Appendix A), this report)
Average Slope Gradient (%)	**3.8%**	**5.5%**	**5.7%**	From Figure A1 (Appendix A), this report)
Average Flow Direction	**NW**	**N**	**NE**	
Time of Concentration, Tc				
a) Grassed areas, Tc (min)	**25**	**19**	**17.5**	Based on CM Plate 1 (overland flow chart)
Value of K	**8,832**	**5,110**	**3,221**	
b) Small agricultural areas, Tc (min)	8.5	5.6	3.9	Based on CM Plate 3, with little or no cover: Tc ≈ $0.0078 \cdot K^{0.77}$, where $K = L/\sqrt{S}$.
10-Year 1-Hour Rainfall (inches)	**2.0**	**2.0**	**2.0**	Based on Plate 4, Island of Maui, 10-Year 1-Hour Rainfall
Rainfall Intensity, I (inches/hour)	**3.0**	**3.4**	**3.7**	Based on Plate 2, for a 2.0" 1-Hour Rainfall and Tc
Flow Rate, Q = C.I.A (cfs)	**19.6**	**18.2**	**8.9**	***Total Q = 46.7 cfs***

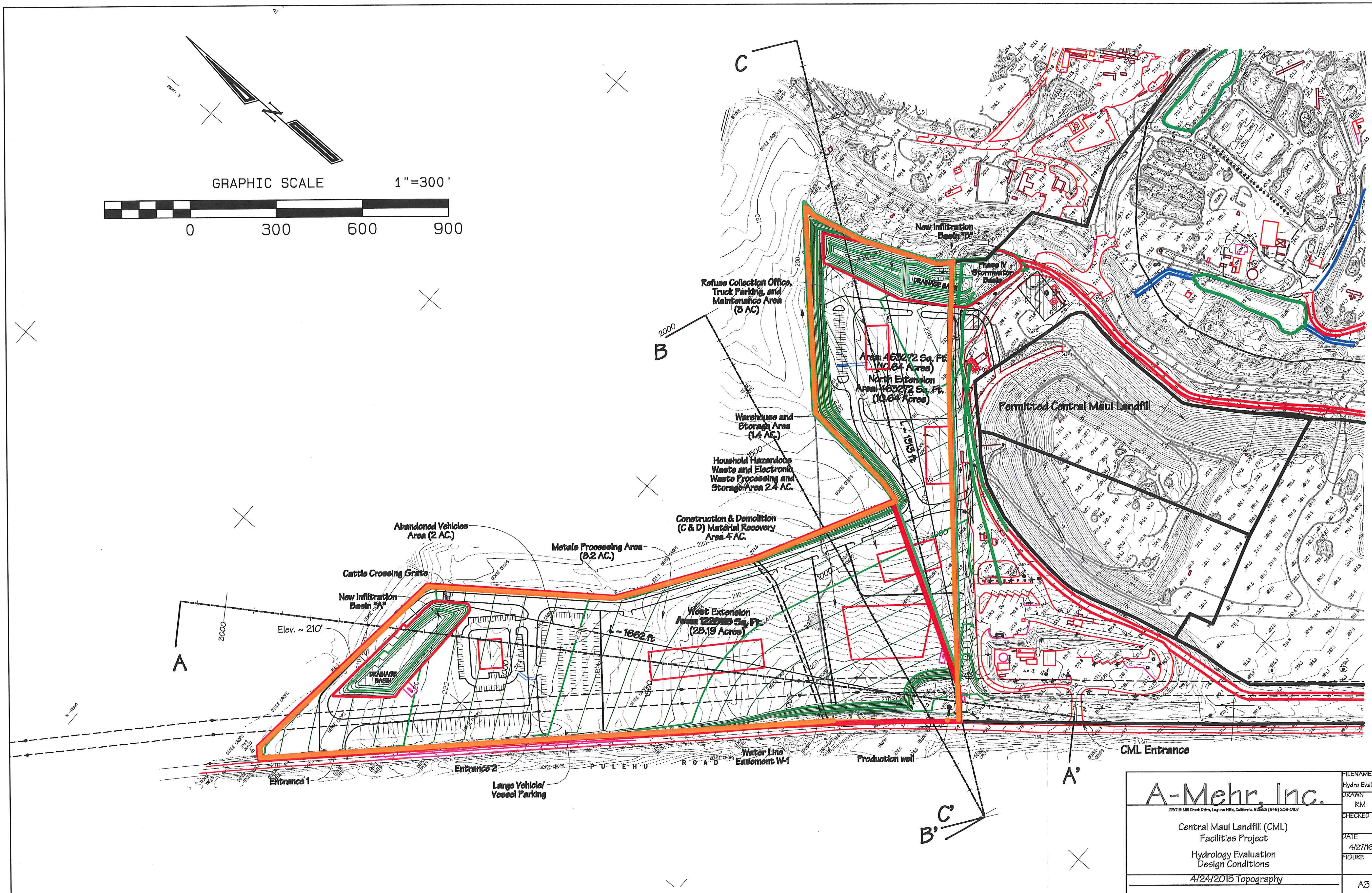
Part 2 - Developed Conditions

Drainage Facilities	West Drainage		North Drainage	Remarks
On-Site Drainage Area, A_d (sq ft) =	1,228,118		463,272	
On-Site Drainage Area, A_d (acres) =	28.19		10.64	
Total Infiltration Basin Capacity, without Freeboard (cubic yards)	14,321		24,271	
Infiltration Basin Capacity, with 1' Freeboard (cubic yards)	12,504		22,231	
Infiltration Basin Capacity (acre-foot) =	7.8		13.8	
Hydrologic Criteria (§15-04-05)				
2.0 Recurrence Interval, Tm (years)	50	50	50	Tm ≈ 50 year based on 1-hour storm, per§15-04-05 items b) for drainage areas Ad < 100 acres with sump; d) design of roadway culverts and bridges; and for e) retention and detention basins.
2.1 - Run-Off Quantity				Per Rational Method of drainage areas of 100 acres or less, Q = CIA based on accompanying tables and charts.
Watershed/Run-off Coefficient, C				Based on Tables 1 or 2, whichever is higher.
Watershed Coefficients for On-Site Areas				
Infiltration	0.20		0.20	Negligible
Relief	0.00		0.03	Flat (2 to 2.5%)
Vegetal Cover	0.05		0.05	Poor (<10%)
Development Type	0.55		0.55	Industrial - Business
$C = \Sigma (C_1 \text{ to } C_4)$	*0.80*		*0.83*	*Built-Up Areas (From CM Table 1)*
Typical for Type of Drainage Area	*0.80*		*0.80*	*Light Industrial Area (From CM Table 2)*
Highest Run-Off Coefficient	**0.80**		**0.83**	From CM Tables 1 and 2
Overland Flow Maximum Length, L (feet)	500		1,313	
Highest Elevation (feet MSL)	250		250	From proposed final ground surface contours (Figures 3 and A2, this report)
Lowest Elevation (feet MSL)	238		217	From proposed final ground surface contours (Figures 3 and A2, this report)
Average Slope Gradient (%)	**2.4%**		**2.5%**	
Time of Concentration, Tc				
a) Paved, bare soil & grassed areas, Tc (min)	**17**		**25**	Based on CM Plate 1, Overland Flow Chart
Value of K	**3,227**		**8,282**	
b) Small agricultural areas, Tc (min)	3.9		8.1	Based on CM Plate 3, Concetration Time of small agricultural areas with little or no cover: Tc ≈ $0.0078 \cdot K^{0.77}$, where $K = L/\sqrt{S}$;
50-Year 1-Hour Rainfall (inches)	**2.5**		**2.5**	Based on CM Plate 7, Island of Maui, for 50-Year 1-Hour Rainfall
Rainfall Intensity, I (inches/hour)	4.3		3.7	Based on CM Plate 2, for a 2.5" 1-Hour Rainfall and Tc
Flow Rate, Q = C.I.A (cfs)	**97.8**		**32.9**	***Total Q = 130.7 cfs***

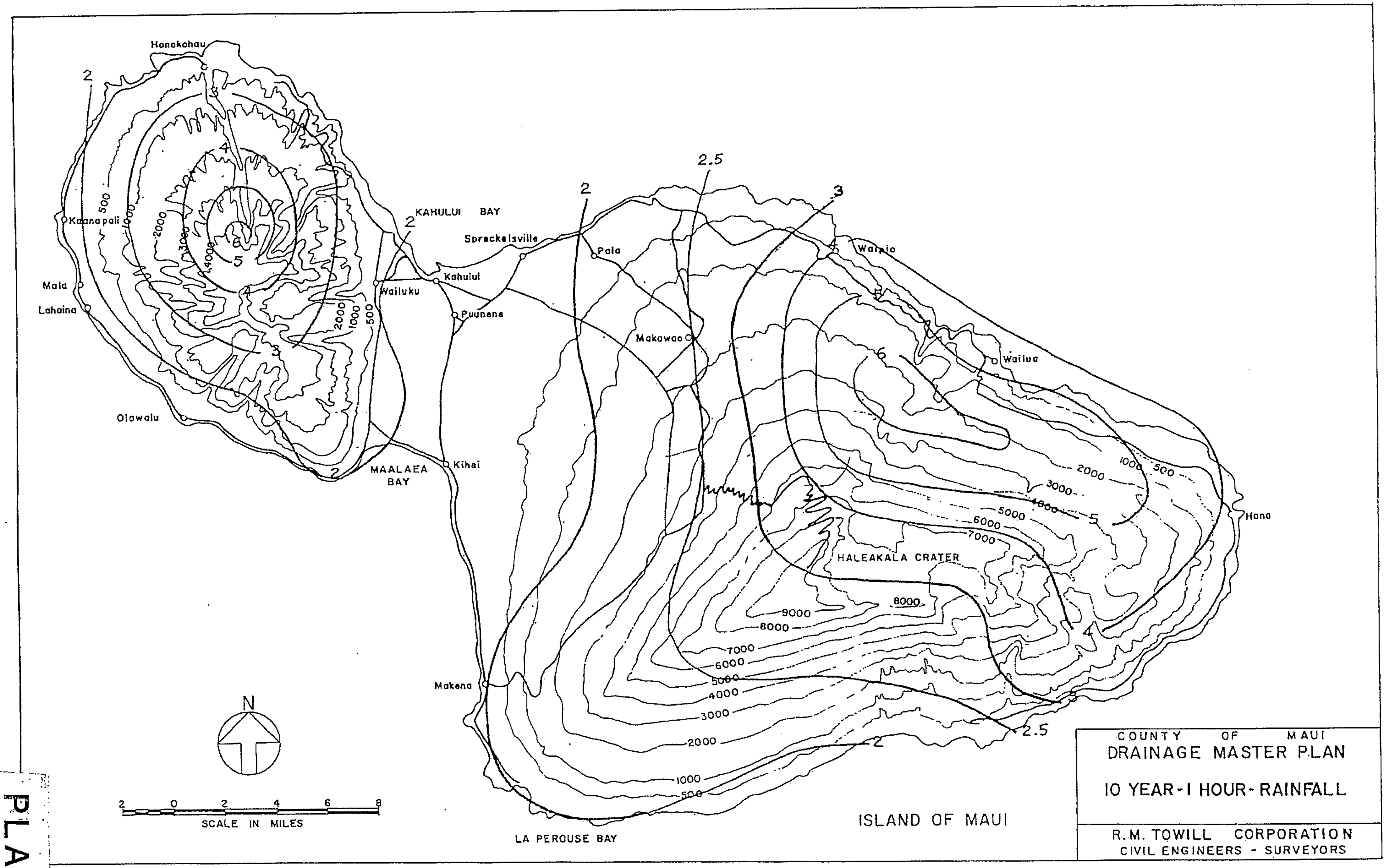

CML Facilities Site
(40.8 Acres)
Haiku Ditch
Haiku Ditch
Haiku Ditch
Electric Transmission
Line Easement
Pulehu Road
Pulehu Rd
Pulehu Rd
West
Expansion
Area
North
Expansion
Area
Phase IV
Permitted Central
Maui Landfill
Perimeter Sugar-Cane Trail
Sugar-Cane Trail
Water Line
Easement
Aqueduct
Village Rd
Village Rd
Reservoir
N
GRAPHIC SCALE
1"=500'
500
1000
1500
A-Mehr, Inc.
Central Maui Landfill (CML)
Facilities Project
Hydrology Evaluation
Site Photograph
Existing Conditions
FILENAME
Hydro Eval
DRAWN
RM
CHECKED
DATE
3/21/16
FIGURE
A1



N
GRAPHIC SCALE
1"=300'
0
300
600
900
Elev. 196'
Phase IV
Stormwater Basin
North Extension Area
Area: 282046.08 Sq. Ft.
(6.47 Acres)
L ~ 710 ft
Elev. 204'
Elev. ~ 240'
L ~ 417 ft
Elev. 216'
Permitted Central Maui Landfill
West Extension Area
Area: 623899.75 Sq. Ft.
(14.32 Acres)
L ~ 792 ft
Elev. ~ 210'
Area: 784561 Sq. Ft.
(18.01 Acres)
L ~ 1718 ft
Electric Line
Easement
Elev. 206'
Elev. 270'
Water Line
Easement
CML Entrance
A-Mehr, Inc.
Central Maui Landfill (CML)
Facilities Project
Hydrology Evaluation
Existing Conditions
4/24/2015 Topography
FILENAME
Hydro Eval
DRAWN
RM
CHECKED
DATE
1/22/16
FIGURE
A2

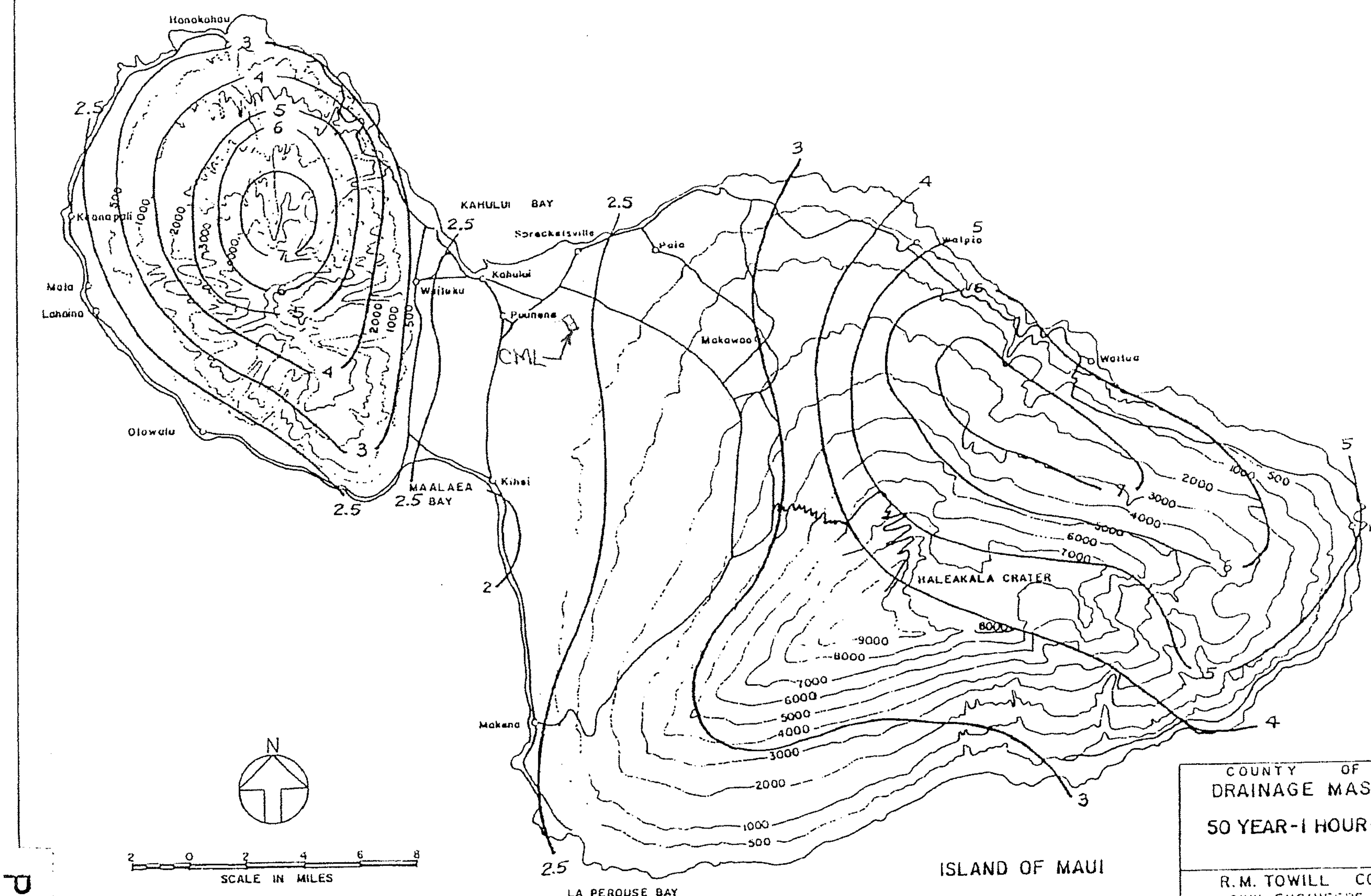


N
GRAPHIC SCALE
1"=300'
0
300
600
900
C
B
A
C'
B'
A'
New Infiltration Basin "B"
Phase IV Stormwater Basin
DRAINAGE BASIN
Refuse Collection Office, Truck Parking, and Maintenance Area (3 AC.)
Area: 463272 Sq. Ft. (10.64 Acres)
North Extension Area: 463272 Sq. Ft. (10.64 Acres)
L ~ 1515 ft
Permitted Central Maui Landfill
Warehouse and Storage Area (1.4 AC.)
Household Hazardous Waste and Electronic Waste Processing and Storage Area 2.4 AC.
Construction & Demolition (C & D) Material Recovery Area 4 AC.
Abandoned Vehicles Area (2 AC.)
Metals Processing Area (8.2 AC.)
Cattle Crossing Grate
New Infiltration Basin "A"
Elev. ~ 210'
L ~ 1662 ft
West Extension
(28.19 Acres)
DRAINAGE BASIN
Entrance 2
Entrance 1
PULEHU ROAD
Water Line Easement W-1
Production well
CML Entrance
Large Vehicle/ Vessel Parking
A-Mehr, Inc.
Central Maui Landfill (CML) Facilities Project
Hydrology Evaluation Design Conditions
4/24/2015 Topography
FILENAME
Hydro Eval
DRAWN
RM
CHECKED
DATE
4/27/16
FIGURE
A3



Honokohau
Kaanapali
Mala
Lahaina
Olowalu
MAALAEA BAY
KAHULUI BAY
Spreckelsville
Kahului
Wailuku
Puunene
Kihei
Paia
Makawao
Waipio
Wailua
Hana
HALEAKALA CRATER
Makena
LA PEROUSE BAY
ISLAND OF MAUI
N
SCALE IN MILES
COUNTY OF MAUI
DRAINAGE MASTER PLAN
10 YEAR-1 HOUR-RAINFALL
R.M. TOWILL CORPORATION
CIVIL ENGINEERS - SURVEYORS

PLATE 4



COUNTY OF MAUI
DRAINAGE MASTER PLAN
50 YEAR-1 HOUR-RAINFALL

R.M. TOWILL CORPORATION
CIVIL ENGINEERS - SURVEYORS

CML → 50-year 1-hr rainfall ≈ 2.5 inches

PLATE 7

Table 1

GUIDE FOR THE DETERMINATION OF RUNOFF COEFFICIENTS FOR BUILT-UP AREAS*

WATERSHED CHARACTERISTICS	EXTREME	HIGH	MODERATE	LOW
INFILTRATION	NEGLIGIBLE 0.20	SLOW 0.14	MEDIUM 0.07	HIGH 0.0
RELIEF	STEEP (> 25%) 0.08	HILLY (15 - 25%) 0.06	ROLLING (5 - 15%) 0.03	FLAT (0 - 5%) 0.0
VEGETAL COVER	NONE 0.07	POOR (< 10%) 0.05	GOOD (10 - 50%) 0.03	HIGH (50 - 90%) 0.0
DEVELOPMENT TYPE	INDUSTRIAL & BUSINESS 0.55	HOTEL - APARTMENT 0.45	RESIDENTIAL 0.40	AGRICULTURAL 0.15

**NOTE:* *The design coefficient "c" must result from a total of the values for all four watershed characteristics of the site.*

Table 2

RUNOFF COEFFICIENTS

Type of Drainage Area	Runoff Coefficient C
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single-family areas	0.50
Multi-units, detached	0.60
Multi-units, attached	0.75
Suburban	0.40
Apartment dwelling areas	0.70
Industrial:	
Light areas	0.80
Heavy areas	0.90
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad-yard areas	0.40
Unimproved areas	0.30
Streets:	
Asphaltic	0.95
Concrete	0.95
Brick	0.85
Drive and walks	0.85
Roofs	0.95
Lawns:	
Sandy, soil, flat, 2%	0.10
Sandy, soil, avg., 2-7%	0.15
Sandy, soil, steep, 7%	0.20
Heavy soil, flat, 2%	0.17
Heavy soil, avg., 2-7%	0.22
Heavy soil, steep, 7%	0.35

Central Maui Landfill (CML)
Phase VI Drainage

Average for East and West Perimeter Channels
L ≈ 475'
S ≈ 33% (3H:1V)

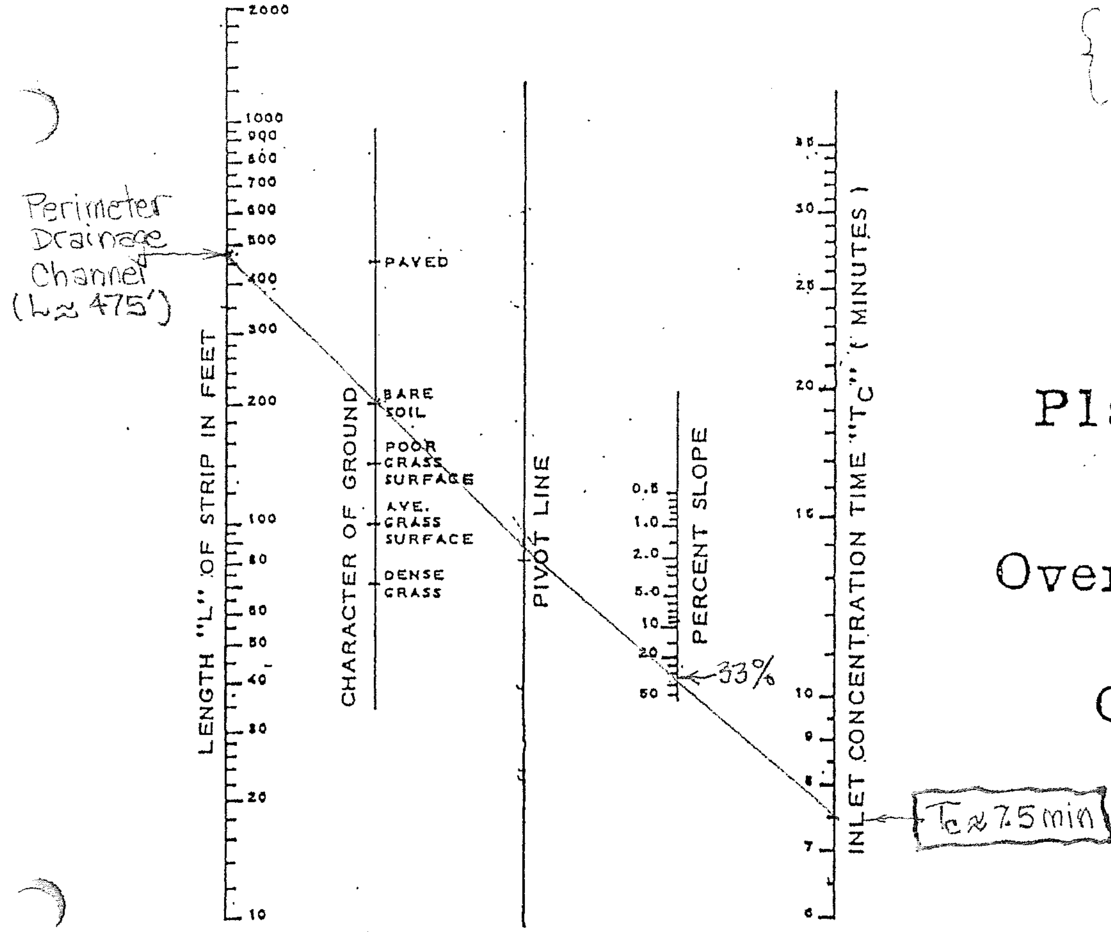
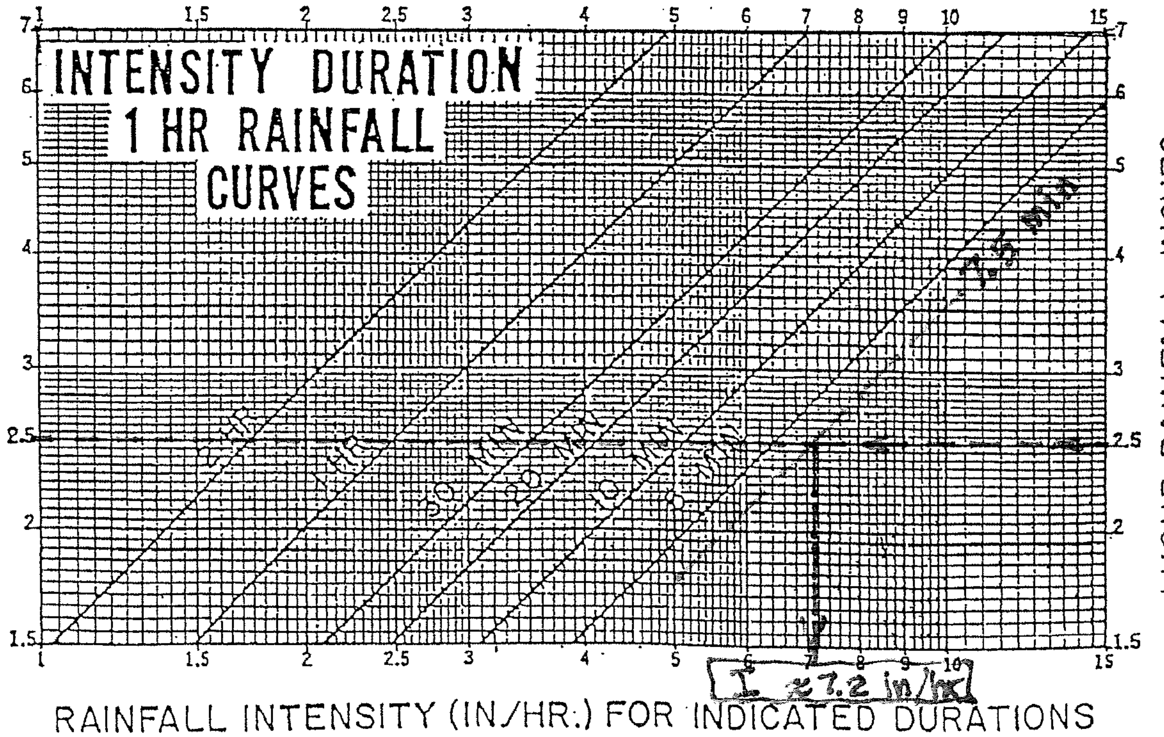
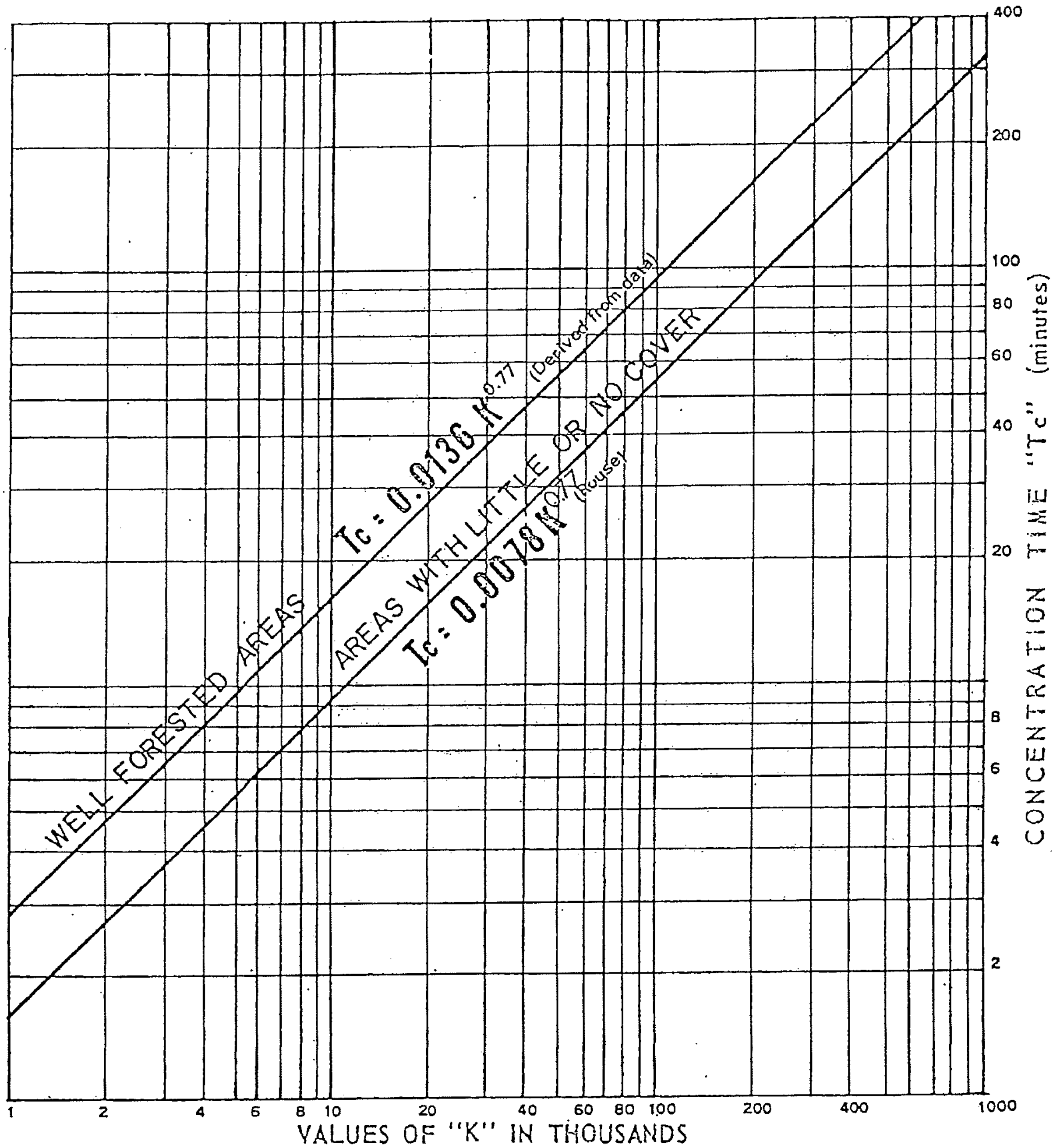


Plate 1

Overland Flow Chart

Plate 2





L = Maximum length of travel in feet
H = Difference in elevation between most remote point and outlet in feet.
S = Slope H/L

$$K = \frac{L}{\sqrt{S}} = \sqrt{\frac{L^3}{H}}$$

Use upper curve for well forested areas.
Use lower curve for areas with little or no cover.

SOURCE: CITY PLANNING COMMISSION
Graph from Hunter Rouse "Engineering Hydrauiics"

Plate 3
Time of Concentration
(OF SMALL AGRICULTURAL DRAINAGE BASIN)

EEV

Manning Equation Calculator	Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

West Channel

Click to Calculate k = 1.49

Solve for:

Velocity and Discharge

Select units:

Use feet and seconds units

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Area, A (ft^2):	25
Wetted Perimeter, P (ft):	27
Channel Slope, S (ft/ft):	0.0096
Manning n:	0.016
Velocity, V (ft/s):	8.6680099 ✓
Discharge, Q (ft^3/s):	216.70025 ✓

Ave. Phase VII Asphalt

Units in Manning calculator: ft=foot, m=meter, s=second.

To: LMNO Engineering home page (more calculations)

Related calculations:

Design of Rectangular Channels

Design of Trapezoidal Channels

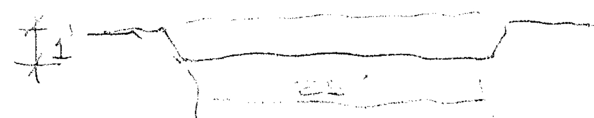
Circular Culverts using Manning Equation

Culvert Design using Inlet and Outlet Control

Q=VA simple flowrate calculator

Manning Equation:

$$Q = VA \qquad V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$



A ≈ 25' x 1' ≈ 25 ft²
P = 25' + 1' + 1' ≈ 27'

k is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).
A=Flow area of the pipe, culvert, or channel.
P=Wetted perimeter which is the portion of the circumference that is in contact with water.
Q=Discharge (flow rate).
S=Downward (longitudinal) slope of the culvert.
V=Average velocity in the pipe, culvert, or channel.

Manning n varies with the roughness of the pipe, culvert, or channel. The higher the n, the rougher the material. Table of Manning n values.

CML - Phase VI EEV

Manning Equation Calculator | Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

West Channel

Click to Calculate k = 1.49

Solve for:

Velocity and Discharge

Select units:

Use feet and seconds units

Area, A (ft^2):	25
Wetted Perimeter, P (ft):	27
Channel Slope, S (ft/ft):	.02
Manning n:	0.016
Velocity, V (ft/s):	12.511195 ✓
Discharge, Q (ft^3/s):	312.77987 ✓

average IV, V, VI
Asphalt

Units in Manning calculator: ft=foot, m=meter, s=second.

To: LMNO Engineering home page (more calculations)

Related calculations:

Design of Rectangular Channels

Design of Trapezoidal Channels

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Culvert Design using Inlet and Outlet Control

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V=Average velocity in the pipe, culvert, or channel.

Manning n varies with the roughness of the pipe, culvert, or channel. The higher the n, the rougher the material. Table of Manning n values.

The Manning Equation is the most commonly used equation to analyze open channel flows. It is a semi-empirical equation for simulating water flows in channels and culverts where the water is open to the atmosphere, i.e. not flowing under pressure, and was first presented in 1889 by Robert Manning. The channel can be any shape - circular, rectangular, triangular, etc. The units in the Manning equation appear to be inconsistent; however, the value k has hidden units in it to make the equation consistent. The Manning Equation was developed for uniform steady state flow (see Discussion and References for Open Channel Flow). S is the slope of the energy grade line and $S=h_f/L$ where h_f is energy (head) loss and L is the length of the channel or reach. For uniform steady flows, the energy grade line = the slope of the water surface = the slope of the bottom of the channel.

The product A/P is also known as the hydraulic radius, R_h.

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Manning n values

Unit Conversions

Other information:

Trouble printing?

Register

Discussion and References for Open Channel Flow

Manning's n Coefficients for Open Channel Flow

The fluid mechanics calculations website

Manning n values compiled from the references listed under Discussion and References as well as the references at the bottom of this page. Manning n has no units.

To: LMNO Engineering Home Page (more calculations)
Circular Culverts using Manning Equation Culvert Design using Inlet and Outlet Control
Trapezoidal Channels Rectangular Channels
Manning Equation Calculator Unit Conversions

Material	Manning n	Material	Manning n
Natural Streams		*Excavated Earth Channels*	
Clean and Straight	0.030	Clean	0.022
Major Rivers	0.035	Gravelly	0.025
Sluggish with Deep Pools	0.040	Weedy	0.030
		Stony, Cobbles	0.035
Metals		*Floodplains*	
Brass	0.011	Pasture, Farmland	0.035
Cast Iron	0.013	Light Brush	0.050
Smooth Steel	0.012	Heavy Brush	0.075
Corrugated Metal	0.022	Trees	0.15
Non-Metals			
Glass	0.010	Finished Concrete	0.012
Clay Tile	0.014	Unfinished Concrete	0.014

Brickwork	0.015	Gravel	0.029
Asphalt	0.016	Earth	0.025
Masonry	0.025	Planed Wood	0.012
		Unplaned Wood	0.013
Corrugated Polyethylene (PE) with smooth inner walls [a,b]			0.009-0.015
Corrugated Polyethylene (PE) with corrugated inner walls [c]			0.018-0.025
Polyvinyl Chloride (PVC) with smooth inner walls [d,e]			0.009-0.011

References

Footnotes refer to Manning n table above. All other Manning n values were obtained from the references listed in our Discussion and References page.

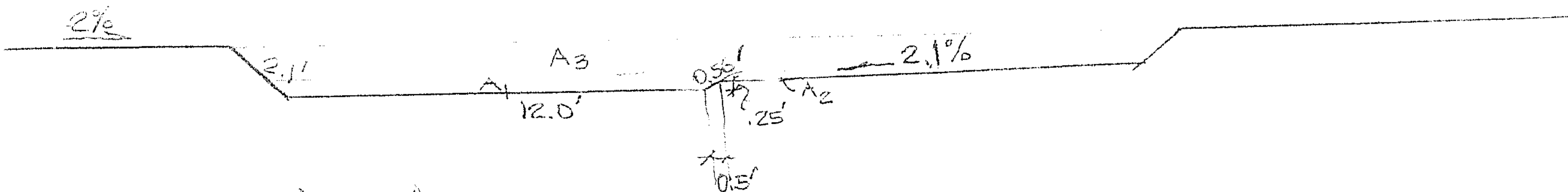
[a] Barfuss, Steven and J. Paul Tullis. Friction factor test on high density polyethylene pipe. Hydraulics Report No. 208. Utah Water Research Laboratory, Utah State University. Logan, Utah. 1988.

[c] Barfuss, Steven and J. Paul Tullis. Friction factor test on high density polyethylene pipe. Hydraulics Report No. 208. Utah Water Research Laboratory, Utah State University. Logan, Utah. 1994.

[e] Bishop, R.R. and R.W. Jeppson. Hydraulic characteristics of PVC sewer pipe in sanitary sewers. Utah State University. Logan, Utah. September 1975.

[d] Neale, L.C. and R.E. Price. Flow characteristics of PVC sewer pipe. Journal of the Sanitary Engineering Division, Div. Proc 90SA3, ASCE. pp. 109-129. 1964.

[b] Tullis, J. Paul, R.K. Watkins, and S. L. Barfuss. Innovative new drainage pipe. Proceedings of the International Conference on Pipeline Design and Installation, ASCE. March 25-27, 1990.



$A = A_1 + A_2 + A_3$

$A_1 = \frac{(12.0' + 12.5')}{2} \times 0.5' \approx 6.12 \text{ ft}^2$

$A_2 = \frac{12' \times 0.25'}{2} \approx 1.5 \text{ ft}^2$

$A_3 = \left(\frac{27' + 25'}{2}\right) \times 1.0' \approx 26 \text{ ft}^2$

$A \approx 6.12 + 1.5 + 26.0 \text{ ft}^2 \approx \underline{33.62 \text{ ft}^2}$
$P \approx 2.1' + 12.0' + 0.56' + 12.0' + 1.4' \approx 26.7 \text{ ft}$
} "high" flow conditions.

$A \approx \frac{12' + 12.5'}{2} \times 0.25' \approx 3.0 \text{ ft}^2$
$P \approx 0.4' + 12' + 0.4' \approx 12.8 \text{ f}$
} "Low" flow conditions.

Manning Equation Calculator	Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

Solve for:

Velocity and Discharge

Select units:

Use feet and seconds units

Click to Calculate k = 1.49

Area, A (ft^2):	33.62
Wetted Perimeter, P (ft):	26.7
Channel Slope, S (ft/ft):	.0296
Manning n:	0.016
Velocity, V (ft/s):	18.682562 ✓
Discharge, Q (ft^3/s):	628.10775 ✓

CML – Phase III East Channel (high flow)
– Average Phase III

Units in Manning calculator: ft=foot, m=meter, s=second.

Manning Equation:

$$Q = VA \qquad V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

k is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).
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Q=Discharge (flow rate).
S=Downward (longitudinal) slope of the culvert.
V=Average velocity in the pipe, culvert, or channel.

Manning n varies with the roughness of the pipe, culvert, or channel. The higher the n, the rougher the material. Table of Manning n values.

To: LMNO Engineering home page (more calculations)

Related calculations:

Design of Rectangular Channels

Design of Trapezoidal Channels

Circular Culverts using Manning Equation

Culvert Design using Inlet and Outlet Control

Q=VA simple flowrate calculator

Manning Equation Calculator | Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

CML - Phase VI

Click to Calculate k = 1.49

Solve for:

Velocity and Discharge

Select units:

Use feet and seconds units

Area, A (ft^2): 33.62

Wetted Perimeter, P (ft): 26.7

Channel Slope, S (ft/ft): .022 — Average (IV, V, VI)

Manning n: 0.016

Velocity, V (ft/s): 16.106528

Discharge, Q (ft^3/s): 541.50146

Units in Manning calculator: ft=foot, m=meter, s=second.

Manning Equation:

$$Q = VA \qquad V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

k is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).
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Culvert Design using Inlet and Outlet Control

Q=VA simple flowrate calculator

Manning Equation Calculator | Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

CML Phase II East Channel "Low" Flow

Click to Calculate k = 1.49

Solve for: Velocity and Discharge

Select units: Use feet and seconds units

Area, A (ft^2):	3
Wetted Perimeter, P (ft):	12.8
Channel Slope, S (ft/ft):	.022
Manning n:	0.016
Velocity, V (ft/s):	5.2507154 ✓
Discharge, Q (ft^3/s):	15.752146 ✓

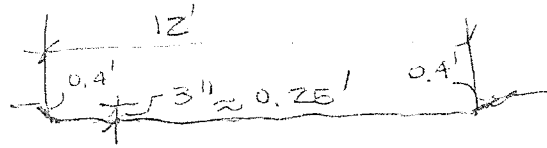
Ave. IV, V, VI

To: LMNO Engineering home page (more calculations)

Units in Manning calculator: ft=foot, m=meter, s=second.

Manning Equation:

$$Q = VA \qquad V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$



$A = 12' \times 0.25' \approx 3.0\ ft^2$

$P \approx 12' + 0.4' + 0.4' \approx 12.8'$

k is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).
A=Flow area of the pipe, culvert, or channel.
P=Wetted perimeter which is the portion of the circumference that is in contact with water.
Q=Discharge (flow rate).
S=Downward (longitudinal) slope of the culvert.
V=Average velocity in the pipe, culvert, or channel.

Manning n varies with the roughness of the pipe, culvert, or channel. The higher the n, the rougher the material. Table of Manning n values.

Related calculations:

- Design of Rectangular Channels
- Design of Trapezoidal Channels
- Circular Culverts using Manning Equation
- Culvert Design using Inlet and Outlet Control
- Q=VA simple flowrate calculator

Manning Equation Calculator	Open channel flow software

Manning equation calculation is mobile-device-friendly as of June 27, 2014

Click to Calculate k = 1.49

Solve for: Velocity and Discharge

Select units: Use feet and seconds units

Area, A (ft^2):	3
Wetted Perimeter, P (ft):	12.8
Channel Slope, S (ft/ft):	.0296
Manning n:	0.016
Velocity, V (ft/s):	6.0905007
Discharge, Q (ft^3/s):	18.271502

Units in Manning calculator: ft=foot, m=meter, s=second.

Manning Equation:

$$Q = VA \qquad V = \frac{k}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

k is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).
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P=Wetted perimeter which is the portion of the circumference that is in contact with water.
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Q=VA simple flowrate calculator