2. STORMWATER QUANTITY AND QUALITY ANALYSES

2.1. Hydrologic and Hydraulic Analysis

Using the storm sewer system maps and the two-foot contour interval topographic map, hydrologic analysis has been performed using the HydroCAD software, an advanced model utilizing TR-20 hydrology techniques. The performance of the system and the overland drainage routes were evaluated for the 100-year return period rainfall event.

In general, about 80-percent or four-fifths of the City drains to the Root River (although not all of those watersheds join the Root River within the City boundaries). An eastern one tenth drains to Oak Creek. A small southwestern portion of the City drains to the Fox River. The Root River and Oak Creek eventually drain to Lake Michigan, while the Fox River eventually drains to the Mississippi River and the Gulf of Mexico.

The City is divided into 15 main watersheds (Figure 3). Within these watersheds, separate sub-watersheds are identified. Each of these sub-watersheds is given an identification designation followed by the watershed number (e.g., EB-1). The sub-watersheds are defined by the storm systems that serve them, topography, and by each stormwater pond that serves that watershed. Table 2.1 shows the area corresponding to each of the sub-watersheds.

Urban storm sewers are generally designed to handle the ten-year storms, while the more severe rainfalls are expected to be handled by surface drainage systems, which, in developing communities like the City of Franklin, consist of streets. In other words, the ability of a given street or roadway to convey the runoff in excess of the pipe capacity will determine if the area surrounding the street is prone to flooding.

As a consequence, the drainage problems based on the pipe network deficiencies consist of frequent nuisance flooding that diminishes the overall quality of life, while the flooding due to a lack of overland emergency flow creates a more important safety threat. The evaluation of water quantity issues combines both of these perspectives.

As part of the evaluation, all water features, whether engineered ponds or natural storage areas, need to be considered. Many of the natural storage areas evaluated in the 1993 Plan were again included in this update, and the engineered ponds constructed since 1993 were added. A map of the City's water features is shown in Figure 4.

Not all engineered ponds were considered hydrologically or hydraulically significant, and were not modeled, because they were either relatively small next to a larger storage area within the same watershed, or they were designed for water quality than for quantity. The combination of engineered ponds and natural storage areas provide a good representation of the actual storage that would occur in a 100-year rainfall event.

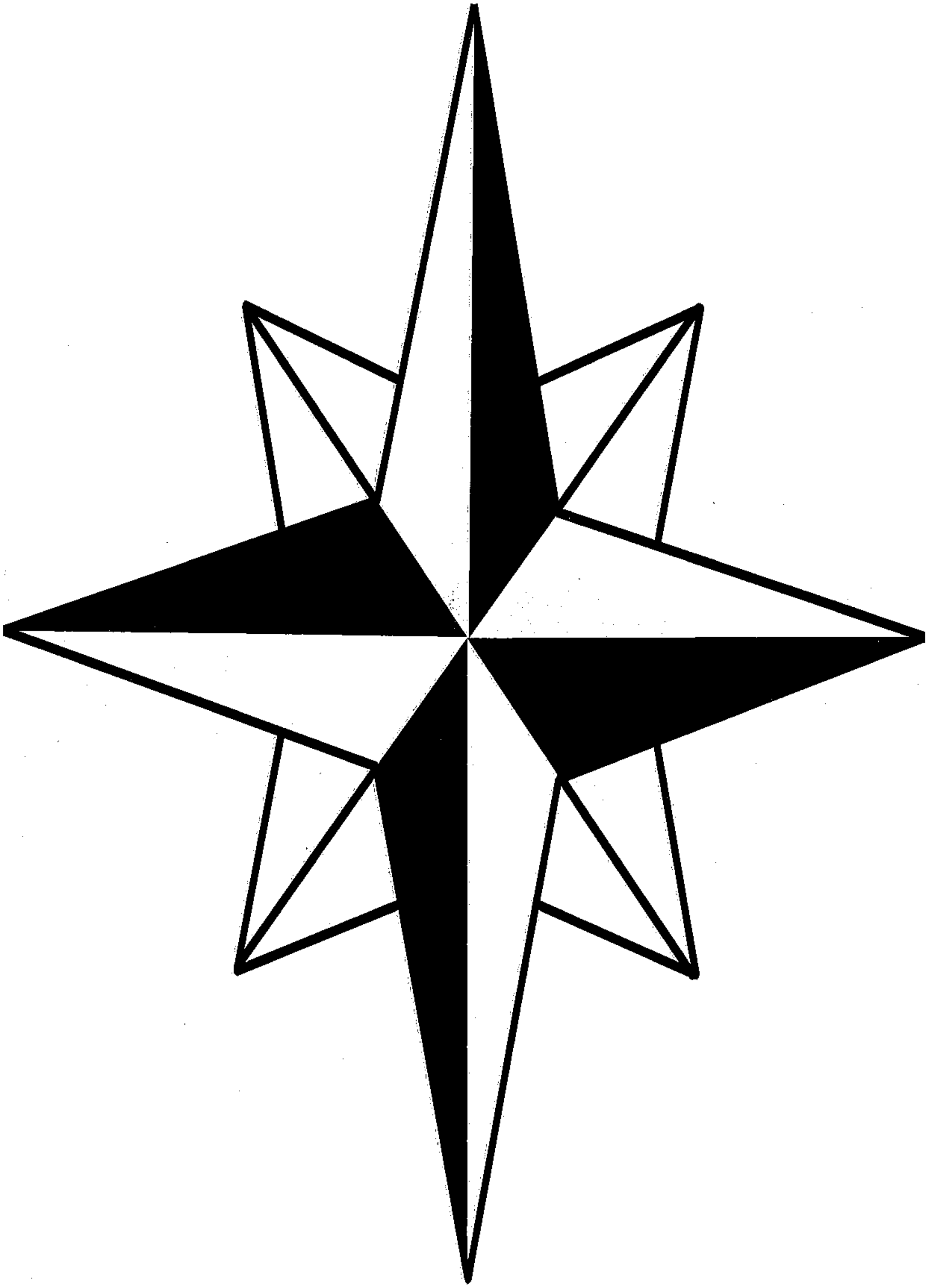
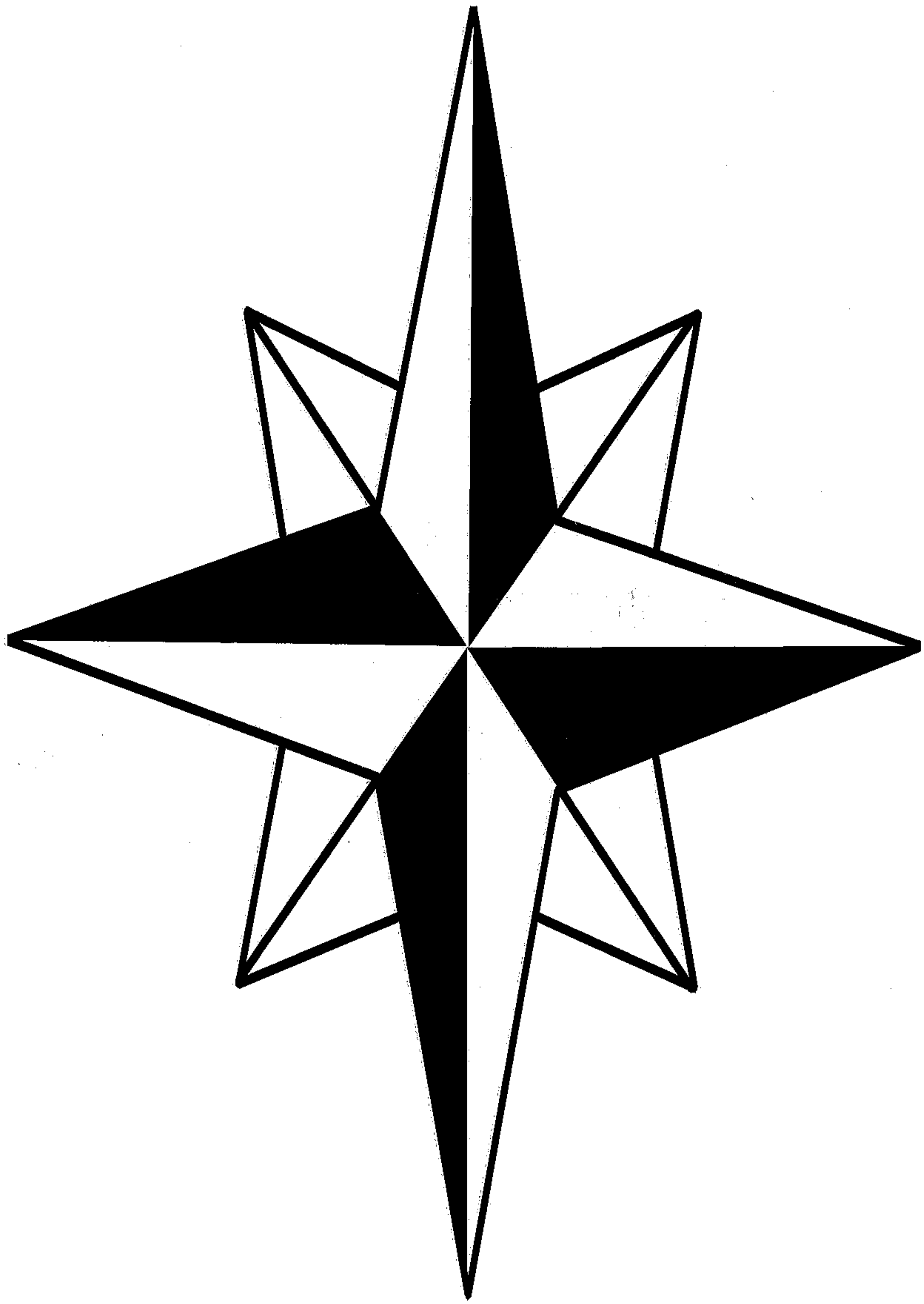


Table 2.1 – The City of Franklin Watersheds and Land Use

Watersheds	Total Area (acre)	Agricultural Area (acres)	Commercial Area (acres)	Environmental Area (acres)	Industrial Area (acres)	Institutional Area (acres)	MineLandfill Area (acres)	Recreational Area (acres)	Residential Area (acres)	Transportation Area (acres)
EB	2,276.38	985.93	84.30	245.02	13.47	116.83	0.00	1.96	790.44	40.45
FX	314.75	125.91	1.34	29.75	29.78	0.00	111.42	0.00	13.74	2.83
LB	236.77	174.47	7.09	25.59	23.62	0.00	0.00	0.00	6.00	0.00
MB	1,069.48	555.23	2.06	155.42	16.98	0.00	0.00	227.23	112.56	0.00
NB	35.47	7.11	20.19	0.00	0.00	5.20	0.00	0.00	2.29	.69
NC	2,515.60	953.68	74.33	411.85	13.72	29.01	0.00	135.10	722.83	125.08
OB	1,458.43	1,069.19	0.70	117.01	0.00	0.00	195.85	0.02	77.66	0.00
OV	132.57	26.76	0.00	3.99	0.00	0.00	0.00	0.30	101.52	0.00
RR	5,278.84	2,417.28	45.64	1,204.71	161.53	54.65	270.39	155.59	855.02	114.23
RRC	415.00	269.31	0.00	129.10	0.00	0.00	0.00	0.00	16.60	0.00
RC	3,380.20	2,476.66	9.28	593.31	3.12	4.97	0.00	9.33	249.70	33.83
TC	2,789.02	465.78	54.33	487.27	46.93	79.41	0.00	232.89	1,289.47	132.93
OC	1,531.87	327.05	40.08	94.47	7.13	32.76	0.00	34.04	971.01	25.33
WE	600.90	486.31	0.00	94.82	0.00	0.00	0.00	0.00	19.78	0.00
WT	978.10	442.42	2.65	98.92	0.00	35.69	0.00	65.53	327.15	5.74



2.1.1. Land Cover Types and Runoff Coefficients

Land cover is one of the most important factors in determining the amount of runoff generated during a rainfall. It is intuitively obvious that an increase in impervious surface areas will lead to higher volumes of rainfall to runoff. For higher Curve Numbers, higher flows and pollutant loads can be expected from the sub-watersheds. The effect of land cover on the runoff computations is specifically defined by the Curve Number, with higher numbers indicating increasing amounts of impervious coverage. This observation is reflected in the SCS Curve Numbers that are presented in the following table.

Table 2.2 – Runoff Coefficients by Land Use Type

Land Use Type	Description	C-Value		(CN) (AMCII)
		10-Year	100-Year	
Residential District				
R-1	Countryside/Estate Single Family	0.39	0.52	75
R-2	Estate Single Family	0.47	0.59	79
R-3	Suburban/Estate Single Family	0.49	0.60	80
R-4	Suburban Single Family	0.49	0.60	80
R-5	Suburban Single Family	0.51	0.62	81
R-6	Suburban Single Family	0.55	0.66	83
R-7	Two-Family Residence	0.55	0.66	83
R-8	Multiple Family Residence	0.71	0.79	90
VR	Village Residence	0.71	0.79	90
Business District				
B-1	Neighborhood Business District	0.76	0.83	92
B-2	General Business District	0.76	0.83	92
B-3	Community Business District	0.76	0.83	92
B-4	South 27th St. Business District	0.76	0.83	92
B-5	Highway Business District	0.76	0.83	92
B-6	Professional Office District	0.76	0.83	92
Industrial District				
M-1	Limited Industrial District	0.76	0.83	92
M-2	General Industrial District	0.76	0.83	92
M-3	Quarrying & Extractive District	0.53	0.64	82
BP	Business Park District	0.85	0.83	94
Public and Semi-Public District				
I-1	Institutional District	0.76	0.83	92
P-1	Park District	0.47	0.59	79
	Ponds	1.0	1.0	99

2.1.2. Runoff Rates and Volumes

The runoff generated within each watershed is computed based on the land use maps providing information on the degree of imperviousness. Naturally, more impervious subwatersheds will generate more runoff than comparably sized subwatersheds of lesser imperviousness.

Runoff is calculated for the 100-year return period rainfall event. The system discharge rates for the 100-year return period rainfall event is obtained as a result of the hydraulic analysis, which is described in the next section of this report.

The two-year 24-hour event is 2.8 inches of rain - a rather common event with a 50-percent chance of occurrence in any given year. The runoff rates and total volumes generated during this event are expected to be handled by the existing storm sewer and other drainage systems without causing flooding. From a water quality point of view, the two-year event also represents the "first flush" of runoff; meaning, most of the pollutants are washed off from the streets by the first two inches of rainfall. As a consequence, detention and settlement of this volume of runoff directly results in effective removal of Nonpoint source pollutants that are carried off during the first flush. The total two-year rainfall runoff volume is a good first estimate of the water quality storage needs associated with each watershed.

The 10-year 24-hour event is 3.9 inches - a relatively rare event with a 10-percent chance of occurrence in any given year. In theory, properly designed and constructed storm systems should be able to handle this 3.9-inch rainfall without street flooding. While portions of the system may experience capacity shortages momentarily, the overall system should perform as designed.

The 100-year 24-hour event is 5.5 inches - a rare event with a one-percent chance of occurrence in any given year. The 100-year event is included in this report because it represents the emergency property protection levels in the City. In theory, properly designed and constructed storm systems (designed for 3.9 in. in 24 hours) would be overwhelmed by the 5.5-inch rainfall. The analysis of the 100-year rainfall gives an indication as to where the excess runoff would go once the storm system is no longer able to cope with the flow.

The hydrologic analysis consisted of predicting flows for each watershed under present conditions for the 100-year rainfall event. This provides baseline information as to the behavior of the present system. From this point forward, the model can be updated as development occurs, so that the impact of the development may be predicted. This is a useful management tool for City staff to use in critiquing future development proposals.

Since 1993, about 100 stormwater ponds have been added throughout the City. While some flooding still occurs, if the ponds were not in place, recent rainfall events would have produced much higher flows in certain parts of the City. In contrast, as one could predict, certain areas within the City that did not have development changes (and the resulting stormwater management efforts), also did not see changes in the amount of flooding that occurred. The City's stormwater management efforts have made an improvement in reducing the peak discharges in certain areas; and that, as development occurs in other areas, one could expect the same flow peak reduction result.

2.1.3. Design Rainfall Selection

There are three commonly used sources of design rainfall depths available that provide data for Southeastern Wisconsin. These are the following:

1. "Rainfall Frequency Atlas of the United States-Technical Paper 40", David Hershfield, May 1961.

2. "Rainfall Frequency Atlas of the Midwest", by Floyd A. Huff and James R. Angel, Illinois State Water Survey Bulletin 71, 1992.

3. Rainfall intensity-duration-frequency data as published by SEWRPC in CAPR No. 152, "Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District", December 1990.

4. Rainfall depth and temporal distribution study as published by SEWRPC in Technical Report No. 40, "Rainfall Frequency in the Southeastern Wisconsin Region", April 2000.

These sources are respectively known as TP-40, Bulletin 71, and the SEWRPC 1990 extreme rainfall depths. A brief description of the methods used to obtain each is provided in the following.

TP-40

TP-40 provides design rainfall depths for the two-, five-, 10-, 25-, 50- and 100-year recurrence interval events for durations of one-half hour, one, two, three, six, 12, and 24 hours. These depths are provided in 48 separate isopluvial contour (contours of equal rainfall depth) maps of the United States. The maps were developed by analysis of the highest quality rainfall records available in the late 1950s. Rainfall quantiles were obtained by fitting the records to the Extreme Value Type 1 (EV1), or Gumbel, distribution. Many of the Gumbel fits were completed in the development of NWS HYDRO 25 documents in 1955. Apparently, considerable smoothing was employed in drawing the TP-40 contour maps. The isopluves (lines of equal rainfall depth) on each map are smooth and sweeping indicating a consistent trend of decreasing rainfall depth with increasing distance from humidity sources such as the Gulf of Mexico. The TP-40 estimate for the 100-year 24-hour rainfall in the southeastern Wisconsin region is approximately 5.5 inches.

In recent years, the dated TP-40 has become less used nationally, although it remains the only source of rainfall depths currently accepted by the Wisconsin Department of Natural Resources. However, the document contains important procedures and findings. These include the widespread use of the Gumbel distribution to fit rainfall, the relationships between "calendar" hour rainfall and peak hour rainfall, and the published selection of durations and recurrence intervals provided in the report, which have since become a standard.

BULLETIN 71

Illinois State Water Survey (ISWS) Bulletin 71 presents the results of an analysis of 275 gauge records in nine Midwestern states including Wisconsin. The computed rainfall depths are presented in two formats: as tables providing rainfall quantiles for each of 76 climatic regions (nine of which are in Wisconsin), and as isopluvial maps. There is an extraordinary difference between the Bulletin 71 maps and the TP-40 maps. The TP-40 maps intend to illustrate the logical variation of rainfall, while the Bulletin 71 maps meticulously document the variations in the result obtained from the analyses of 275 rainfall records. The difference can mislead users who are familiar with TP-40. The highs and lows of the Bulletin 71 maps usually indicate the locations of anomalous gauge records, rather than real regional trends.

The Bulletin 71 results are based on a computational procedure that is unknown outside Huff's own publications. The method relies on fitting a curve to a plot of the logarithm of the estimated recurrence interval versus the logarithm of extreme rainfall. Daily records are primarily used in the method. Short duration storms were derived according to ratios obtained from a few hourly records and studies previously conducted by Huff in Illinois. Only three gauge records used in the Bulletin 71 analysis are located in the southeastern Wisconsin area.

SEWRPC 1990

Early comprehensive estimates of rainfall frequency were conducted around 1955 for the HYDRO-25 study by the U.S. Weather Bureau using Milwaukee rainfall recorded from 1903 through 1951. The HYDRO-25 results were incorporated into the isopluvial maps published as TP-40. In 1969, SEWRPC conducted an independent analysis of rainfall frequency (SEWRPC, 1973). Like TP-40, the estimates were based on fits to the Extreme Value Type 1 (EV1), or Gumbel distribution. The Milwaukee rainfall gauge, now located at General Mitchell Field, was the only long record available. The SEWRPC analysis extended the period of record used for NWS HYDRO-25 and TP-40 by 15 years, considering rainfalls from 1903 through 1966. The additional 15 years of data had little impact on the estimated 100-year 24-hour rainfall yielding an estimate of 5.71 inches.

Shortly after the storm of August 6, 1986, SEWRPC reevaluated the rainfall series that had now grown to 84 years (from 1903 through 1986). Once again, the estimates were derived by fitting to the Gumbel distribution. This analysis resulted in an estimated 100-year 24-hour rainfall of about 5.5 inches (SEWRPC, 1990). This design depth, along with the other data, have generally served as the design standard in southeastern Wisconsin for the past 10 years.

SEWRPC 2000

Significant advancements in statistical procedures used to characterize rainfall prompted SEWRPC to consult with outside experts in this 2000 review and evaluation of rainfall design depths. This consultation has resulted in a major change in the methods used to derive design rainfall. Previous analyses used techniques similar to the procedures then in use by the National Weather Service (NWS), and generally confirmed NWS results. The SEWRPC 2000 study uses a new statistical procedure, which is consistent with new NWS methods; and, the resulting depths are generally higher than previous estimates.

The recommended design rainfall for stormwater management calculation in the City of Franklin is the TP-40 rainfall depths used with the SCS type temporal distribution. Though recent SEWRPC studies have provided more up-to-date design rainfall and temporal distribution information, the TP-40 rainfall is currently the only depth accepted by the WDNR. Therefore, the use of TP-40 in Franklin will ensure compatibility with WDNR regulatory review procedures.

It is our understanding that the SEWRPC 2000 study, which provides a modern revision to the older TP-40 and SEWRPC 1990 rainfall depths, is currently under review by the National Weather Service. In the event that NWS agrees with the study findings, the SEWRPC 2000 rainfall information would be eligible for consideration by the WDNR for regulatory review. We therefore recommend that, upon WDNR approval, the City of Franklin add SEWRPC 2000 to the list of acceptable design rainfalls for stormwater management computations.

2.2. Pollutant Load Assessment

As part of the Nonpoint Source Pollution Abatement Program, a baseline determination of the pollutant loading generated within the City limits will be modeled using the spreadsheet approximation of the Source Loading And Management Model (SLAMM) computer model.

SLAMM is most appropriately used to evaluate the effects of different development characteristics and control practices for small rains that are of most interest in water quality evaluations. These evaluations can be used to set priorities for retrofitting urban runoff controls in developed areas and to select the most appropriate sets of controls for different types of future developments. SLAMM cannot be used to directly design water quality controls, but it can be used to quickly compare the benefits of alternative designs and combinations of controls.

Some of the features of SLAMM can be useful in supplementing large storm hydraulic analyses (such as the calculation of curve numbers reflecting the water volume benefits of water quality controls and specific development characteristics). However, SLAMM is not capable of conducting or evaluating hydraulic designs. SLAMM can also be used to supplement receiving water analyses for water quality. The predicted outfall discharges, reflecting specific development characteristics and control practices, can be used in many lake and stream models.

The spreadsheet method calculates annual unit area loads in pounds based on runoff coefficients for different land use types. The calculations are limited to five pollutants: sediment, phosphorus, zinc, copper, and lead. The input requirements consist of drainage characteristics and land use types by sub-basin. The spreadsheet method is less technical than SLAMM and requires minimal input parameters. However, the method addresses fewer pollutants (5 versus 12 in SLAMM) and the output is less accurate than SLAMM. The unit pollutant loading used for computations was calibrated for the Milwaukee Metropolitan area characteristics; and, the results are within acceptable accuracy limits for water quality evaluations.

The results of the pollutant load assessment can be found in Appendix B. The pollutant loads, for each pollutant, are shown for each sub-watershed and summed to obtain the total load for each watershed. The pollutant load totals for each watershed are shown in the following discussion.

2.2.1. Pollutant Loads for Each Land Use

The pollutant loading from each sub-watershed will depend on the land use within the sub-watershed. The City Land Use map has been generalized to show nine land use districts and unit pollutant generation from each district must be added to obtain the cumulative pollutant loading from all districts present in each sub-watershed. This is equivalent to developing an effective pollutant load for each sub-watershed in proportion of the district area within that particular sub-watershed.

Note that the impact of pollutants on the water body will not be assessed since the total pollutant loading to the Root River has not been computed. As a consequence, this study will not calculate the benefits of any improvements on the receiving waters. Instead, the results will give an indication as to the pollution reduction that can be achieved in the City of Franklin.

The 1995 Land Use plan is the latest available plan able to generalize and assign pollutant loads. Some land uses had to be adjusted due to known development in certain areas. The pollutant load method used provides an estimation of the loads. It can be used for comparative analysis rather than for exact loadings within each watershed. By estimating the amount of pollutants captured in future stormwater ponds, the reduced pollutant loading can be predicted.

Table 2.3 represents the annual pollutant loads for each land use district in the City of Franklin. The sum of pollutant amounts from all zoning districts within a given sub-watershed represents the loading from the sub-watershed outfall to the receiving water body.

Table 2.3 – Annual Unit Area Pollutant Loading Rates

Pollutant Loadings (Lb./ac.-yr)					
Land Uses	Sediment	Phosphorous	Lead	Copper	Zinc
Residential	512	0.47	0.32	0.14	0.20
Commercial	1056	1.07	2.70	0.40	2.10
Industrial	280	0.27	2.40	0.50	7.30
Institutional	512	0.47	0.32	0.14	0.20
Mine/Dump	280	0.27	2.40	0.50	7.30
Transportation	1056	1.07	2.70	0.40	2.10
Recreation	124	0.09	0.10	0.10	0.10
Agricultural	450	0.86	0.10	0.10	0.10
Environmental	3	0.03	0.10	0.10	0.10

2.2.2. Pollutant Loads at Each Outfall

Using the unit pollutant loads and the distribution of different land uses within each sub-watershed, the yearly pollutant load expected to be discharged from each outfall can be estimated as shown in Table 2.4.

Table 2.4 – Pollutant Loads at Each Watershed

Watersheds	Area (acre)	Sediment (lbs/yr)	Phosphorus (lbs/yr)	Lead (lbs/yr)	Zinc (lbs/yr)	Copper (lbs/yr)
East Branch (EB)	2,276.38	1,044,672	1,419	783	665	307
Fox River (FX)	314.75	107,711	158	370	1,058	90
Lower Branch (LB)	236.77	95,762	168	98	209	35
Middle Branch (MB)	1,069.48	343,059	562	176	245	119
North Branch of the Oak Creek (NB)	35.47	29,075	32	59	46	10
North Central Tributary (NC)	2,515.60	1,072,109	1,439	978	829	349
Oakwood Branch (OB)	1,458.43	575,923	1,011	615	1,565	228
Orchard View Tributary (OV)	132.57	64,068	71	36	23	17
Root River (RR)	5,278.84	1,866,191	2,844	2,137	4,048	785
Root River Canal (RRC)	415.00	130,074	243	45	43	42
Ryan Creek (RC)	3,380.20	1,294,217	2,315	513	472	362
Tess Corners Creek (TC)	2,789.02	1,151,702	1,293	1,175	1,128	409
Upper Oak Creek (OC)	1,531.87	736,676	831	560	436	216
Willow Edge Tributary (WE)	600.90	229,248	430	64	62	61
Woodview Tributary (WT)	978.10	402,144	569	199	151	115

2.2.3. Normalized Pollutant Loads at Each Outfall

The total pollutant loads for each watershed are been shown above; however, each of the pollutants within the watershed can be viewed a different way – as normalized. The total pollutant loads for each pollutant is divided by the watershed area, thereby giving a weighted pollutant unit load over the watershed. This presents a way to see which watershed produces the most unit load for each pollutant. The normalized pollutant unit loads are shown below in Table 2.5.

Table 2.5 – Normalized Pollutant Unit Loadings at Each Watershed

Watersheds	Area (acre)	Sediment (lbs/ac-yr)	Phosphorus (lbs/ac-yr)	Lead (lbs/ac-yr)	Zinc (lbs/ac-yr)	Copper (lbs/ac-yr)
East Branch (EB)	2,276.38	458.92	0.62	0.34	0.29	0.13
Fox River (FX)	314.75	342.21	0.50	1.18	3.36	0.29
Lower Branch (LB)	236.77	404.45	0.71	0.41	0.88	0.15
Middle Branch (MB)	1,069.48	320.77	0.53	0.16	0.23	0.11
North Branch of the Oak Creek (NB)	35.47	819.77	0.90	1.68	1.30	0.29
North Central Tributary (NC)	2,515.60	426.18	0.57	0.39	0.33	0.14
Oakwood Branch (OB)	1,458.43	394.89	0.69	0.42	1.07	0.16
Orchard View Tributary (OV)	132.57	483.29	0.53	0.27	0.18	0.13
Root River (RR)	5,278.84	353.52	0.54	0.40	0.77	0.15
Root River Canal (RRC)	415.00	313.43	0.59	0.11	0.10	0.10
Ryan Creek (RC)	3,380.20	382.88	0.68	0.15	0.14	0.11
Tess Corners Creek (TC)	2,789.02	412.94	0.46	0.42	0.40	0.15
Upper Oak Creek (OC)	1,531.87	480.90	0.54	0.37	0.28	0.14
Willow Edge Tributary (WE)	600.90	381.51	0.72	0.11	0.10	0.10
Woodview Tributary (WT)	978.10	411.15	0.58	0.20	0.15	0.12