

# Graphs of Climate Change SWMM Results

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## Analysis of simulated vs observed runoff

```
#Graph observed vs simulated runoff for Max Multiplicative Change Factor (MCF)
```

```
observed<- read.csv(here("climate_change_data","SWMM_results", "Mar14_observed.csv"))
simulated_max_march14 <- read.csv(here("climate_change_data","SWMM_results", "MCF_max_Mar14_simulated.csv"))
simulated_min_march14 <- read.csv(here("climate_change_data","SWMM_results", "MCF_min_Mar14_simulated.csv"))
```

```
# merge MCF max with observed
```

```
discharge_MCF_max<- merge(observed, simulated_max_march14, by = "time_step")
```

```
#merge MCF min with observed
```

```
discharge_MCF_min<- merge(observed, simulated_min_march14, by = "time_step")
```

```
summary(discharge_MCF_max)
```

```
graph_max<- ggplot(discharge_MCF_max, aes(x=discharge_obs_cfs, simulated_flow_cfs))+
  geom_point()
```

```
graph_max
```

```
graph_min<- ggplot(discharge_MCF_min, aes(x=discharge_obs_cfs, simulated_flow_cfs))+
  geom_point()
```

```
graph_min
```

```
calibrate_graph_max<- discharge_MCF_max %>%
  ggplot()+
  geom_line(aes(x=time_step, y=discharge_obs_cfs), color="#000000", size = 2.5)+
  geom_line(aes(x=time_step, y=simulated_flow_cfs), color= "#009E73", size = 2.5)+
  theme_classic()+
  labs(x="Time (hours)", y="Discharge (cfs)")+
  scale_y_continuous(limits= c(0,850), breaks= seq(0,850, by= 100),expand= c(0,0))+
  scale_x_continuous(limits= c(0,12), breaks= seq(0,12, by= 2),expand= c(0,0))+
  annotate("text", label= "Observed", x=10.5, y=85, size=8)+
  annotate("text", label= "Simulated", x=10.5, y=300, size=8) +
  theme(text = element_text(size=22))
```

```
calibrate_graph_max
```

```
calibrate_graph_min<- discharge_MCF_min %>%
  ggplot()+
  geom_line(aes(x=time_step, y=discharge_obs_cfs), color="#000000", size =2.5) +
  geom_line(aes(x=time_step, y=simulated_flow_cfs), color= "#009E73", size =2.5)+
  theme_classic()+
  labs(x="Time (hours)", y="Discharge (cfs)")+
  scale_y_continuous(limits= c(0,400), breaks= seq(0,350, by= 50),expand= c(0,0))+
  scale_x_continuous(limits= c(0,12), breaks= seq(0,12, by= 2),expand= c(0,0))+
  annotate("text", label= "Simulated", x=10.5, y=45, size=8)+
  annotate("text", label= "Observed", x=10.5, y=185, size=8) +
  theme(text = element_text(size=22))
```

```
calibrate_graph_min
```

```
# save graphs
# ggsave('discharge_mar14_max_MCF.png', calibrate_graph_max, width = 16, height = 9, units = "in")

# ggsave('discharge_mar14_min_MCF.png', calibrate_graph_min, width = 16, height = 9, units = "in")
```

```
## combine all three lines onto one graph for easabilty
```

```
calibrate_graph <- ggplot()+
  geom_line(data = discharge_MCF_min, aes(x=time_step, y=discharge_obs_cfs), color="#000000", size =2.5)
  geom_line(data= discharge_MCF_min, aes(x=time_step, y=simulated_flow_cfs), color= "#009E73", size =2.5)
  geom_line(data= discharge_MCF_max, aes(x=time_step, y=simulated_flow_cfs), color= "#D55E00", size = 2.5)
  theme_classic()+
  labs(x="Time (hours)", y="Discharge (cfs)")+
  scale_y_continuous(limits= c(0,850), breaks= seq(0,850, by= 100),expand= c(0,0))+
  scale_x_continuous(limits= c(0,12), breaks= seq(0,12, by= 2),expand= c(0,0))+
  annotate("text", label= "Observed", x=10.5, y=200, size=8)+
  annotate("text", label= "Max MCF Simulated", x=10.5, y=655, size=8) +
  annotate("text", label= "Min MCF Simulated", x=10.5, y=55, size=8) +
  theme(text = element_text(size=22))
```

```
calibrate_graph
```

```
# ggsave('discharge_mar14_MCF.png', calibrate_graph, width = 16, height = 9, units = "in")
```

## Analysis of MCF max storm results

```
subcatch_max_mcf<- read_csv("subcatchments_all.csv") %>%
  mutate(subcatchment= OBJECTID_1) %>%
  select(subcatchment, Curve_Number, Slope, percent_imp, Area_sqft)

swm_results_max_mcf<-read_csv("Wailupe_MCF_Max_Mar14.csv")

#Characterize results by urbanization level
results_max_mcf<- merge(subcatch_max_mcf, swm_results_max_mcf, by = "subcatchment") %>%
  mutate(runoff_normalized=
    total_runoff_in/Area_sqft) %>%
  mutate(Urbanization_level=
    case_when(
```

```

    percent_imp <15 |percent_imp == 15 ~ "Natural (less than 15 % Impervious)",
    percent_imp >15 & percent_imp <45 ~ "Urbanized (Between 15 and 45 % Impervious)",
    percent_imp >44.9999 ~ "Very urbanized (More than 45 % Impervious)"
  )
)

write.csv(results_max_mcf, file = "results_max_mcf.csv") ##Export as .csv for use with graph maps

## normalize peak discharge (cfs) for max MCF by dividing by subcatchment area
results_max_mcf_normalized <- results_max_mcf %>%
  mutate(peak_runoff_cfs_norm = peak_runoff_cfs/Area_sqft)

results_maxmcf_peakflow_table <- results_max_mcf %>%
  select(subcatchment, peak_runoff_cfs, Curve_Number, Slope, percent_imp, Area_sqft) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(peak_runoff_cfs)) %>%
  top_n(20,peak_runoff_cfs) %>%
  kable(col.names=c("Subcatchment", "Peak Runoff (cfs)", "Max MCF",
                    "Curve Number", "Slope",
                    "Percent Impervious", "Area (sqft)")) %>%
  kable_styling(bootstrap_options = "striped")

results_maxmcf_peakflow_table

results_maxmcf_peakflow_table_normalized <- results_max_mcf_normalized %>%
  select(subcatchment, peak_runoff_cfs, Curve_Number, Slope, percent_imp, Area_sqft,peak_runoff_cfs_norm)
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(peak_runoff_cfs_norm)) %>%
  top_n(20,peak_runoff_cfs_norm) %>%
  kable(col.names=c("Subcatchment", "Peak Runoff (cfs)", "Max MCF",
                    "Curve Number", "Slope",
                    "Percent Impervious", "Area (sqft)", "Normalized Peak Runoff (cfs/sqft)"))
  kable_styling(bootstrap_options = "striped")

results_maxmcf_peakflow_table_normalized

results_maxmcf_runoffcoef_table <- results_max_mcf %>%
  select(subcatchment, runoff_coef, Curve_Number, Slope, percent_imp, Area_sqft) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(runoff_coef)) %>%
  top_n(20,runoff_coef) %>%
  kable(col.names=c("Subcatchment", "Runoff Coefficient", "Max MCF",
                    "Curve Number", "Slope",
                    "Percent Impervious", "Area (sqft)")) %>%
  kable_styling(bootstrap_options = "striped")

results_maxmcf_runoffcoef_table

#Perform a linear regression for the SWMM max MCF storm results
results_max_mcf_regression<- lm(total_runoff_in ~Curve_Number + Slope + percent_imp +
                               Area_sqft, data = results_max_mcf)

#Graph the relationship bw simulated runoff and impervious cover by urbanization level

```

```

runoff_imp_graph_max_mcf<- results_max_mcf %>%
  ggplot(aes(x=percent_imp, y=total_runoff_in))+
  geom_point(aes(color=Urbanization_level))+
  labs(x= "Percent Impervious of Subcatchment", y= "Total Simulated Runoff (inches)")+
  scale_y_continuous(limits= c(0,8), breaks= seq(0,8, by= 1),expand= c(0,0.08))+
  scale_x_continuous(limits= c(0,80), breaks= seq(0,80, by= 10),expand= c(0,0))+
  scale_color_manual(name= "Urbanization Level", values= c("darkgreen", "darkseagreen",
                                                         "darkgoldenrod1"))+

  theme_classic()

runoff_imp_graph_max_mcf

#Save runoff vs. impervious graph
# ggsave("runoff_imp_max_mcf.pdf", width = 8, height =4)
# ggsave("runoff_imp_max_mcf.png", width = 8, height =4)

#Create a table for the regression results for max mcf storm
regress_table_max_mcf<- stargazer(results_max_mcf_regression, type ="html", digits= 2,
                                dep.var.labels = "Total Runoff (Inches)",
                                covariate.labels = c("Curve Number", "Slope", "Percent Impervious",
                                                      "Area (sqft)", "Y-Intercept"),
                                omit.stat = c("rsq"))

regress_table_max_mcf

```

## Analysis of MCF min storm results

```

subcatch_min_mcf<- read_csv("subcatchments_all.csv") %>%
  mutate(subcatchment= OBJECTID_1) %>%
  select(subcatchment, Curve_Number, Slope, percent_imp, Area_sqft)

swm_results_min_mcf<-read_csv("Wailupe_MCF_Min_Mar14.csv")

#Characterize results by urbanization level
results_min_mcf<- merge(subcatch_min_mcf, swm_results_min_mcf, by = "subcatchment") %>%
  mutate(runoff_normalized=
    total_runoff_in/Area_sqft) %>%
  mutate(Urbanization_level=
    case_when(
      percent_imp <15 |percent_imp == 15 ~ "Natural (less than 15 % Impervious)",
      percent_imp >15 & percent_imp <45 ~ "Urbanized (Between 15 and 45 % Impervious)",
      percent_imp >44.9999 ~ "Very urbanized (More than 45 % Impervious)"
    )
  )

write.csv(results_min_mcf, file = "results_min_mcf.csv") ##Export as .csv for use with graph maps

## normalize peak discharge (cfs) for min MCF by dividing by subcatchment area
results_min_mcf_normalized <- results_min_mcf %>%
  mutate(peak_runoff_cfs_norm = peak_runoff_cfs/Area_sqft)

results_minmcf_peakflow_table <- results_min_mcf %>%
  select(subcatchment, peak_runoff_cfs, Curve_Number, Slope, percent_imp, Area_sqft) %>%

```

```

filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
arrange(desc(peak_runoff_cfs)) %>%
top_n(20,peak_runoff_cfs) %>%
kable(col.names=c("Subcatchment", "Peak Runoff (cfs), Min MCF",
                  "Curve Number", "Slope",
                  "Percent Impervious", "Area (sqft)")) %>%
kable_styling(bootstrap_options = "striped")

results_minmcf_peakflow_table

results_minmcf_peakflow_normalized_table <- results_min_mcf_normalized %>%
  select(subcatchment, peak_runoff_cfs, Curve_Number, Slope, percent_imp, Area_sqft, peak_runoff_cfs_norm)
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(peak_runoff_cfs_norm)) %>%
  top_n(20,peak_runoff_cfs_norm) %>%
  kable(col.names=c("Subcatchment", "Peak Runoff (cfs), Min MCF",
                    "Curve Number", "Slope",
                    "Percent Impervious", "Area (sqft)", "Normalized Peak Runoff (cfs/sqft)")) %>%
  kable_styling(bootstrap_options = "striped")

results_minmcf_peakflow_normalized_table

results_minmcf_runoffcoef_table <- results_min_mcf %>%
  select(subcatchment, runoff_coef, Curve_Number, Slope, percent_imp, Area_sqft) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(runoff_coef)) %>%
  top_n(20,runoff_coef) %>%
  kable(col.names=c("Subcatchment", "Runoff Coefficient, Min MCF",
                    "Curve Number", "Slope",
                    "Percent Impervious", "Area (sqft)")) %>%
  kable_styling(bootstrap_options = "striped")

results_minmcf_runoffcoef_table

#Perform a linear regression for the SMM max MCF storm results
results_min_mcf_regression<- lm(total_runoff_in ~Curve_Number + Slope + percent_imp +
                              Area_sqft, data = results_min_mcf)

#Graph the relationship bw simulated runoff and impervious cover by urbanization level
runoff_imp_graph_min_mcf<- results_min_mcf %>%
  ggplot(aes(x=percent_imp, y=total_runoff_in))+
  geom_point(aes(color=Urbanization_level))+
  labs(x= "Percent Impervious of Subcatchment", y= "Total Simulated Runoff (inches)")+
  scale_y_continuous(limits= c(0,7), breaks= seq(0,7, by= 1),expand= c(0,0.08))+
  scale_x_continuous(limits= c(0,80), breaks= seq(0,80, by= 10),expand= c(0,0))+
  scale_color_manual(name= "Urbanization Level", values= c("darkgreen", "darkseagreen",
                                                         "darkgoldenrod1"))+
  theme_classic()

runoff_imp_graph_min_mcf

#Save runoff vs. impervious graph
# ggsave("runoff_imp_min_mcf.pdf", width = 8, height =4)

```

```
# ggsave("runoff_imp_min_mcf.png", width = 8, height =4)

#Create a table for the regression results
regress_table_min_mcf<- stargazer(results_min_mcf_regression, type ="html", digits= 2,
                                dep.var.labels = "Total Runoff (Inches)",
                                covariate.labels = c("Curve Number", "Slope", "Percent Impervious",
                                "Area (sqft)", "Y-Intercept"),
                                omit.stat = c("rsq"))
regress_table_min_mcf
```

## Maps of SWMM Results

### Maps for MCF max storm hotspots

```
results_max_mcf<- read_csv("results_max_mcf.csv") ##read in file from code above

#Combine subcatchments outline with wet storm results
subcatch_max <- read_sf(dsn = here("climate_change_data", "SWMM_results","shapefiles"), layer = "subcat
  st_transform(st_crs(4326)) %>%
  clean_names() %>%
  select(subcatchment = objectid_1) %>%
  merge(results_max_mcf) %>%
  filter(subcatchment != "5")

# Total volume hotspots
hotspots_max_mcf_total <- tm_basemap("OpenStreetMap.Mapnik") +
  tm_shape(subcatch_max, unit = "Miles") +
  tm_polygons("runoff_coef", alpha = 0.8, palette = "Blues", style = "cont", n=8,
              legend.hist = TRUE, title = "Runoff Coefficient") +
  tm_layout(title = "March 2009 Max MCF storm", inner.margins=c(.05, .05, 0.1, .53),
             legend.position = c(.6,.32), legend.title.size = 1.4, legend.text.size = 1) +
  tm_text("subcatchment", size = 0.3) +
  tm_scale_bar(position = c(.6,.59), breaks = c(0, 0.2, 0.4, 0.6, 0.8,1)) +
  tm_compass(position = c(.58,.52))

# tmap_save(hotspots_max_mcf_total, here("climate_change_data", "output_maps","hotspots_mcf_max.png"))

# Peak flow hotspots
hotspots_max_mcf_peak <- tm_basemap("OpenStreetMap.Mapnik") +
  tm_shape(subcatch_max, unit = "Miles") +
  tm_polygons("peak_runoff_cfs", alpha = 0.75, palette = "Greens", style = "cont", n=8,
              legend.hist = TRUE, title = "Peak Discharge (cfs)") +
  tm_layout(title = "March 2009 Max MCF storm", inner.margins=c(.05, .05, 0.1, .53),
             legend.position = c(.6,.27), legend.title.size = 1.4, legend.text.size = 1) +
  tm_text("subcatchment", size = 0.3) +
  tm_scale_bar(position = c(.6,.54), breaks = c(0, 0.2, 0.4, 0.6, 0.8,1)) +
  tm_compass(position = c(.58,.47))
#tmap_save(hotspots_max_mcf_peak, here("climate_change_data", "output_maps","hotspots_max_mcf_peak.png"))

subcatch_max_peak <- subcatch_max %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
```

```

geom_sf(aes(fill = peak_runoff_cfs)) +
theme_bw() +
scale_fill_gradient(low = "#D1F2EB", high = "#148F77", name = "Peak Discharge (cfs)",
                    breaks = c(0, 25, 50, 75, 100 )) +
labs(title = "Max MCF") +
geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
# geom_sf_label(aes(label = subcatchment), size = 1.5) +
theme(axis.title.x = element_blank(),
      axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90))+
  theme(axis.text.x = element_blank(),
        axis.text.y = element_blank(),
        axis.ticks = element_blank(),
        rect = element_blank(),
        panel.border=element_blank()) +
  theme_void() # for faculty presentation, remove lines and axis elements

subcatch_max_peak

# ggsave('subcatch_max_peak_removedsubs_themvoid.png', subcatch_max_peak, width = 5, height = 7, units

subcatch_max_total <- subcatch_max %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
  geom_sf(aes(fill = runoff_coeff)) +
  theme_bw() +
  scale_fill_gradient(low = "#D6EAF8", high = "#2874A6", name = "Runoff Coefficient",
                    breaks = c(0, 0.2, 0.4, 0.6, 0.8, 1.0),
                    limits = c(0,1.0)) +
  labs(title = "Max MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
        axis.title.y = element_blank()) +
  theme(axis.text.x = element_text(angle = 90)) +
    theme(axis.text.x = element_blank(),
          axis.text.y = element_blank(),
          axis.ticks = element_blank(),
          rect = element_blank(),
          panel.border=element_blank()) +
    theme_void()

subcatch_max_total

# ggsave('subcatch_max_total.png', subcatch_max_total, width = 5, height = 7, units = "in")

```

## Maps for MCF min storm hotspots

```

results_min_mcf<- read_csv("results_min_mcf.csv") ##read in file from code above

#Combine subcatchments outline with wet storm results
subcatch_min <- read_sf(dsn = here("climate_change_data", "SWMM_results","shapefiles"), layer = "subcat
  st_transform(st_crs(4326)) %>%

```



```

clean_names() %>%
select(subcatchment = objectid_1) %>%
merge(results_min_mcf) %>%
  filter(subcatchment != "5")

# Total volume hotspots
hotspots_min_mcf_total <- tm_basemap("OpenStreetMap.Mapnik") +
  tm_shape(subcatch_min, unit = "Miles") +
  tm_polygons("runoff_coeff", alpha = 0.8, palette = "Blues", style = "cont", n=8,
    legend.hist = TRUE, title = "Runoff Coefficient") +
  tm_layout(title = "March 2009 Min MCF storm", inner.margins=c(.05, .05, 0.1, .53),
    legend.position = c(.6,.32), legend.title.size = 1.4, legend.text.size = 1) +
  tm_text("subcatchment", size = 0.3) +
  tm_scale_bar(position = c(.6,.59), breaks = c(0, 0.2, 0.4, 0.6, 0.8,1)) +
  tm_compass(position = c(.58,.52))
##tmap_save(hotspots_wet_total, here("5.Results_Maps", "output_maps", "hotspots_wet_total.png"))

# Peak flow hotspots
hotspots_min_mcf_peak <- tm_basemap("OpenStreetMap.Mapnik") +
  tm_shape(subcatch_min, unit = "Miles") +
  tm_polygons("peak_runoff_cfs", alpha = 0.75, palette = "Greens", style = "cont", n=8,
    legend.hist = TRUE, title = "Peak Discharge (cfs)") +
  tm_layout(title = "March 2009 Min MCF storm", inner.margins=c(.05, .05, 0.1, .53),
    legend.position = c(.6,.27), legend.title.size = 1.4, legend.text.size = 1) +
  tm_text("subcatchment", size = 0.3) +
  tm_scale_bar(position = c(.6,.54), breaks = c(0, 0.2, 0.4, 0.6, 0.8,1)) +
  tm_compass(position = c(.58,.47))
##tmap_save(hotspots_wet_peak, here("5.Results_Maps", "output_maps", "hotspots_wet_peak.png"))

subcatch_min_peak <- subcatch_min %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
  geom_sf(aes(fill = peak_runoff_cfs)) +
  theme_classic()+
  scale_fill_gradient(low = "#D1F2EB", high = "#148F77", name = "Peak Discharge (cfs)",
    breaks = c(0, 3, 6, 9, 12, 15)) +
  labs(title = "Min MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
    axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90)) +
  theme(axis.text.x = element_blank(),
    axis.text.y = element_blank(),
    axis.ticks = element_blank(),
    rect = element_blank(),
    panel.border=element_blank()) +
  theme_void() # for facily presentation, remove lines and axis elements

subcatch_min_peak

# ggsave('subcatch_min_peak_removedsub_themevoid.png', subcatch_min_peak, width = 5, height = 7, units

```



```

subcatch_min_total <- subcatch_min %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
  geom_sf(aes(fill = runoff_coeff)) +
  theme_bw() +
  scale_fill_gradient(low = "#D6EAF8", high = "#2874A6", name = "Runoff Coefficient",
    breaks = c(0, 0.2, 0.4, 0.6, 0.8, 1.0),
    limits = c(0,1.0)) +
  labs(title = "Min MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
    axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90)) +
  theme(axis.text.x = element_blank(),
    axis.text.y = element_blank(),
    axis.ticks = element_blank(),
    rect = element_blank(),
    panel.border=element_blank()) +
  theme_void()

subcatch_min_total

# ggsave('subcatch_min_total.png', subcatch_min_total, width = 5, height = 7, units = "in")

```

## Normalized Peak Discharge Maps

```

subcatch_max_normalized <- read_sf(dsn = here("climate_change_data", "SWMM_results","shapefiles"), layer = 1)
st_transform(st_crs(4326)) %>%
clean_names() %>%
select(subcatchment = objectid_1) %>%
merge(results_max_mcf_normalized) %>%
  filter(subcatchment != "5")

## normalized Max MCF Peak Discharge
subcatch_max_peak_normalized <- subcatch_max_normalized %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
  geom_sf(aes(fill = peak_runoff_cfs_norm)) +
  theme_bw() +
  scale_fill_gradient(low = "#D1F2EB", high = "#148F77", name = "Normalized Peak Discharge (cfs/sqft)") +
  labs(title = "Max MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
    axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90))+
  theme(axis.text.x = element_blank(),
    axis.text.y = element_blank(),
    axis.ticks = element_blank(),
    rect = element_blank(),
    panel.border=element_blank()) +
  theme_void() # for faculty presentation, remove lines and axis elements

```

```

subcatch_max_peak_normalized

# ggsave('subcatch_max_peak_removedsubs_themevoid_norm.png', subcatch_max_peak_normalized, width = 5, h

subcatch_min_normalized <- read_sf(dsn = here("climate_change_data", "SWMM_results", "shapefiles"), layer
  st_transform(st_crs(4326)) %>%
  clean_names() %>%
  select(subcatchment = objectid_1) %>%
  merge(results_min_mcf_normalized) %>%
  filter(subcatchment != "5")

## normalized Min MCF Peak Discharge
subcatch_min_peak_normalized <- subcatch_min_normalized %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  ggplot() +
  geom_sf(aes(fill = peak_runoff_cfs_norm)) +
  theme_classic() +
  scale_fill_gradient(low = "#D1F2EB", high = "#148F77", name = "Normalized Peak Discharge (cfs/sqft)") +
  labs(title = "Min MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 1.8) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
        axis.title.y = element_blank()) +
  theme(axis.text.x = element_text(angle = 90)) +
  theme(axis.text.x = element_blank(),
        axis.text.y = element_blank(),
        axis.ticks = element_blank(),
        rect = element_blank(),
        panel.border=element_blank()) +
  theme_void() # for facily presentation, remove lines and axis elements

subcatch_min_peak_normalized

# ggsave('subcatch_min_peak_removedsub_themevoid_norm.png', subcatch_min_peak_normalized, width = 5, h

```

## binned runoff coefficient maps for min and max MCF

```

# View a single RColorBrewer palette by specifying its name
display.brewer.pal(n = 7, name = 'Blues')

# Hexadecimal color specification
brewer.pal(n = 7, name = "Blues")

mycols <- brewer.pal(n = 11, name = "Blues")
mybreaks_max<- c(0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9)

subcatch_min_total <- subcatch_min %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  mutate(runoff_coeff_cut = cut_number(runoff_coeff, n = 10)) %>%
  ggplot() +
  geom_sf(aes(fill = runoff_coeff_cut)) +
  theme_bw() +

```

```

scale_fill_gradientn(colours = mycols,
                     breaks= mybreaks_max,
                     super = metR::ScaleDiscretised,
                     name = "Runoff Coefficient") +
theme(legend.position = "bottom") +
labs(title = "Min MCF") +
geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 3.1) +
# geom_sf_label(aes(label = subcatchment), size = 1.5) +
theme(axis.title.x = element_blank(),
      axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90)) +
theme(axis.text.x = element_blank(),
      axis.text.y = element_blank(),
      axis.ticks = element_blank(),
      rect = element_blank(),
      panel.border=element_blank()) +
theme_void()

subcatch_min_total

# ggsave('subcatch_min_total_binned.png', subcatch_min_total, width = 5, height = 7, units = "in")

mycols <- brewer.pal(n = 11, name = "Blues")
mybreaks_max<- c(0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9)

subcatch_max_total <- subcatch_max %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  mutate(runoff_coeff_cut = cut_number(runoff_coeff, n = 10)) %>%
ggplot() +
geom_sf(aes(fill = runoff_coeff_cut)) +
theme_bw() +
scale_fill_gradientn(colours = mycols,
                     breaks= mybreaks_max,
                     super = metR::ScaleDiscretised,
                     name = "Runoff Coefficient") +
labs(title = "Max MCF") +
geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 3.1) +
# geom_sf_label(aes(label = subcatchment), size = 1.5) +
theme(axis.title.x = element_blank(),
      axis.title.y = element_blank()) +
theme(axis.text.x = element_text(angle = 90)) +
theme(axis.text.x = element_blank(),
      axis.text.y = element_blank(),
      axis.ticks = element_blank(),
      rect = element_blank(),
      panel.border=element_blank()) +
theme_void()

subcatch_max_total

# ggsave('subcatch_max_total_binned.png', subcatch_max_total, width = 5, height = 7, units = "in")

```

## binned peak flow maps for min and max MCF

```

mycols2 <- brewer.pal(n = 11, name = "Greens")
mybreaks2_min<- c(0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0)

subcatch_min_peak <- subcatch_min %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  mutate(peak_runoff_cfs_cut = cut_number(peak_runoff_cfs, n = 11)) %>%
  ggplot() +
  geom_sf(aes(fill = peak_runoff_cfs_cut)) +
  theme_classic()+
  scale_fill_gradientn(colours = mycols2,
                      breaks= mybreaks2_min,
                      super = metR::ScaleDiscretised,
                      name = "Peak Discharge (cfs)") +
  labs(title = "Min MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 3.1) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
        axis.title.y = element_blank()) +
  theme(axis.text.x = element_text(angle = 90)) +
  theme(axis.text.x = element_blank(),
        axis.text.y = element_blank(),
        axis.ticks = element_blank(),
        rect = element_blank(),
        panel.border=element_blank()) +
  theme_void() # for facily presentation, remove lines and axis elements

subcatch_min_peak

# ggsave('subcatch_min_peak_removedsub_themevoid_binned.png', subcatch_min_peak, width = 5, height = 7)

mycols3 <- brewer.pal(n = 11, name = "Greens")
mybreaks3_max<- c(0.0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)

subcatch_max_peak <- subcatch_max %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  mutate(peak_runoff_cfs_cut = cut_number(peak_runoff_cfs, n = 11)) %>%
  ggplot() +
  geom_sf(aes(fill = peak_runoff_cfs_cut)) +
  theme_classic()+
  scale_fill_gradientn(colours = mycols3,
                      breaks= mybreaks3_max,
                      super = metR::ScaleDiscretised,
                      name = "Peak Discharge (cfs)") +
  labs(title = "Max MCF") +
  geom_sf_text(aes(label = subcatchment), colour = "black", fontface = "bold", size = 3.1) +
  # geom_sf_label(aes(label = subcatchment), size = 1.5) +
  theme(axis.title.x = element_blank(),
        axis.title.y = element_blank()) +
  theme(axis.text.x = element_text(angle = 90))+
  theme(axis.text.x = element_blank(),
        axis.text.y = element_blank(),
        axis.ticks = element_blank(),

```

```

    rect = element_blank(),
    panel.border=element_blank()) +
  theme_void() # for faculty presentation, remove lines and axis elements

subcatch_max_peak

```

```

# ggsave('subcatch_max_peak_removedsubs_themevoid_binned.png', subcatch_max_peak, width = 5, height = 7

```

combine max and min runoff coefficient results into single table showing the catchment #, min, and max runoff coefficient, slope, percent impervious, and area (sqft)

```

results_min_mcf_rc <- results_min_mcf %>%
  select(subcatchment, Slope, percent_imp, Area_sqft, runoff_coef) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(runoff_coef)) %>%
  top_n(20,runoff_coef)

results_max_mcf_rc <- results_max_mcf %>%
  select(subcatchment, Slope, percent_imp, Area_sqft, runoff_coef) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(runoff_coef)) %>%
  top_n(20,runoff_coef)

results_runoffcoef_table <- results_min_mcf_rc %>%
  full_join(results_max_mcf_rc, by=c("subcatchment", "Slope", "percent_imp", "Area_sqft")) %>%
  kable(col.names=c("Subcatchment", "Slope", "Percent Impervious", "Area (sqft)", "Runoff Coefficient, Min",
                    "Runoff Coefficient, Max MCF")) %>%
  kable_styling(bootstrap_options = "striped")

results_runoffcoef_table

```

combine max and min peak runoff (cfs) results into single table showing the catchment #, min, and max peak runoff (cfs)

```

results_min_mcf_peak <- results_min_mcf %>%
  select(subcatchment, Slope, percent_imp, Area_sqft, peak_runoff_cfs) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(peak_runoff_cfs)) %>%
  top_n(20,peak_runoff_cfs)

results_max_mcf_peak <- results_max_mcf %>%
  select(subcatchment, Slope, percent_imp, Area_sqft, peak_runoff_cfs) %>%
  filter(!subcatchment %in% c(1, 2,94,3,38, 24)) %>%
  arrange(desc(peak_runoff_cfs)) %>%
  top_n(20,peak_runoff_cfs)

results_peakflow_table <- results_min_mcf_peak %>%
  full_join(results_max_mcf_peak, by=c("subcatchment", "Slope", "percent_imp", "Area_sqft")) %>%
  kable(col.names=c("Subcatchment", "Slope", "Percent Impervious", "Area (sqft)", "Peak Runoff (cfs), Min",
                    "Peak Runoff (cfs), Max MCF")) %>%
  kable_styling(bootstrap_options = "striped")

```

```
results_peakflow_table
```

## comparing historical vs Max MCF runoff coefficients from Dornan et al., 2020

```
## runoff coefficients differences
dornan_results_top20_rc <- read_csv("~/Desktop/Aloha-Aina-Master/climate_change_data/SWMM_results/dornan_results_top20_rc.csv")
select(subcatchment, runoff_coeff) # read in dornan et al RC results

results_max_mcf_rc_summary <- results_max_mcf_rc %>% select(subcatchment, runoff_coeff) # select just max mcf rc

combined_rc_results <- dornan_results_top20_rc %>% right_join(results_max_mcf_rc_summary, by = c("subcatchment"))

combined_rc_results = combined_rc_results %>% mutate(subtract = runoff_coeff.y-runoff_coeff.x) # add difference

## peak flow differences
dornan_results_top20_peakflow <- read_csv("~/Desktop/Aloha-Aina-Master/climate_change_data/SWMM_results/dornan_results_top20_peakflow.csv")
select(subcatchment, peak_runoff_cfs) # read in Team Kahuawais peak flow results

results_max_mcf_peak_summary <- results_max_mcf_peak %>% select(subcatchment, peak_runoff_cfs) # select just max mcf peak

combined_peak_results <- dornan_results_top20_peakflow %>% right_join(results_max_mcf_peak_summary, by = c("subcatchment"))

combined_peak_results = combined_peak_results %>% mutate(subtract = peak_runoff_cfs.y-peak_runoff_cfs.x)
```